DLR magazine

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THE POWER OF SALT

Research for the Energiewende:
Test facility for new storage technologies is in operation

DRIVING TOWARDS AUTOMATION: Intelligent vehicles

'SOLO' SPACE ODYSSEY: Robots for planetary exploration

LIGHTER FOR THE SHORT HAUL: Fibre-metal laminates for aircraft manufacturing

Image: Barbara Frommann

DLRmagazine 154·155

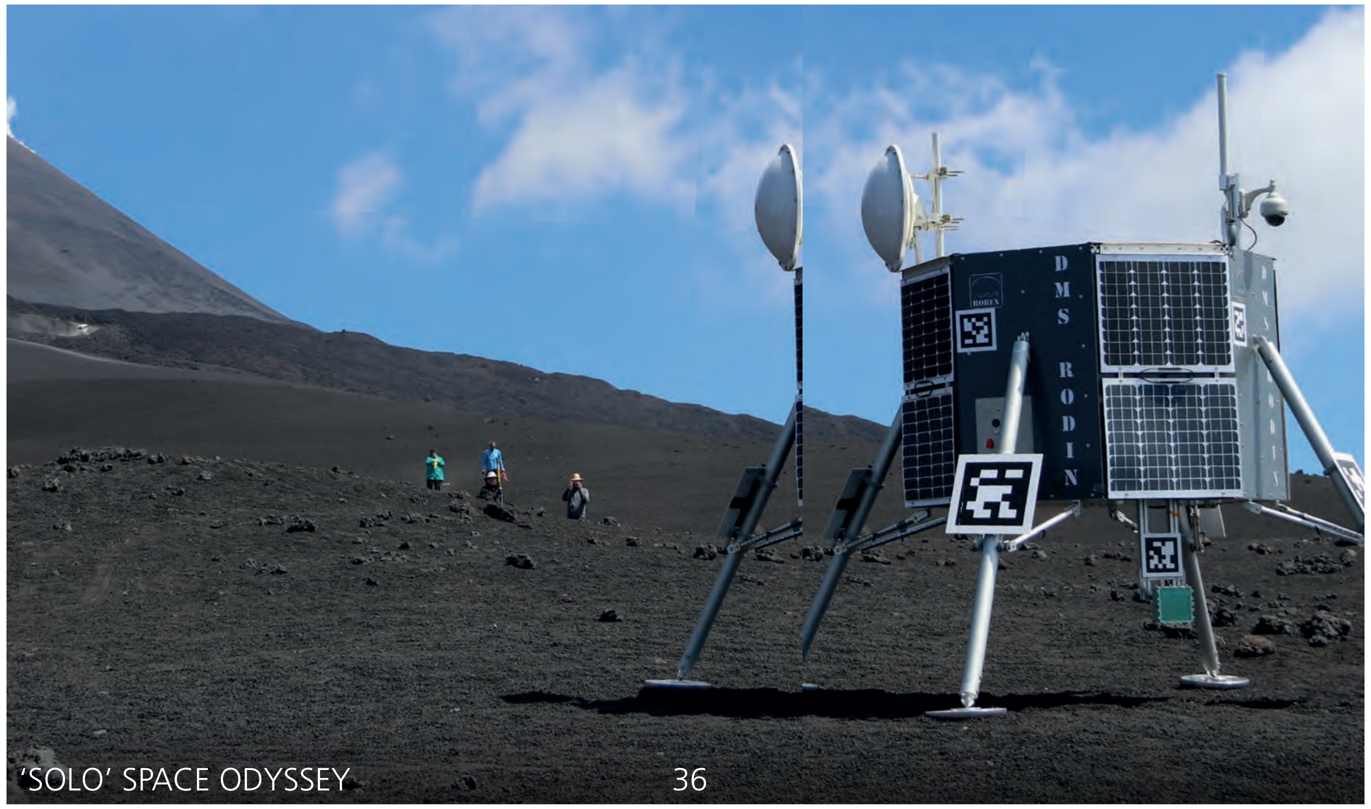
Dear readers,

There are only a few days left until the German federal election on 24 September 2017. The election manifestos laid out by the established parties focus, among other things, on Germany's innovative strength and sustainability. With the adoption of the 'DLR Strategy 2030' and the decision to set up seven new institutes, the DLR Senate laid the foundations for the centre's future back in June. The aim of the 'DLR Strategy 2030' is to reinforce DLR's core competencies and specifically exploit synergy potential across all areas of research. A new addition to this is the cross-disciplinary field of digitalisation.

The current German presidency of the G20 – the group of the 20 most important industrialised nations and emerging economies – shows how justified we are in this approach. In their final summit declaration, the heads of state and government stated that: "Mastering the challenges of our age and shaping an interconnected world is the common goal of the G20 as our premier forum for international economic cooperation." The G20 further states that the "digital transformation is a driving force of global, innovative, inclusive and sustainable growth, and can contribute to reducing inequality and achieving the goals of the 2030 Agenda for Sustainable Development".

With our diverse research topics and expanded portfolio at 20 locations across Germany in over 40 institutes and facilities, the Space Administration and the Project Management Agency, we are creating unique technological and social added value. Thus, we will more effectively than before communicate DLR's contributions to Germany as a business and innovation hub, as well as highlight how our excellent research and competitiveness contribute to solving the global challenges that we face today.

Matthias Ruchser
Head of Public Affairs and Communications



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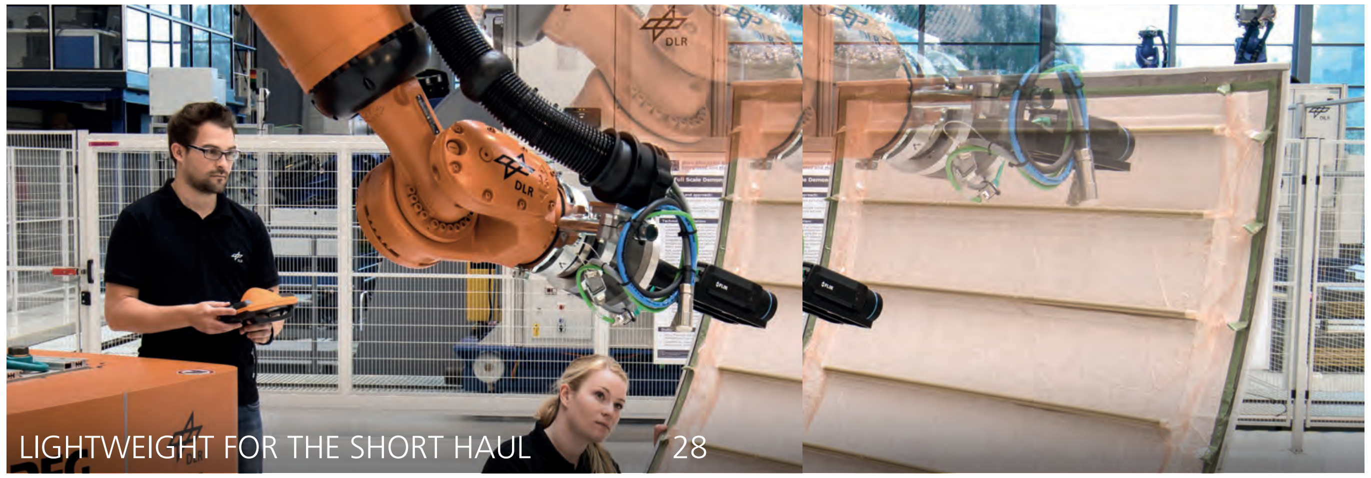

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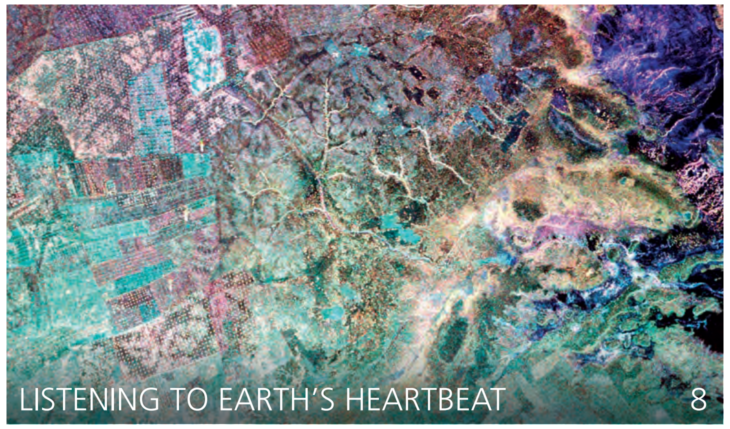

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"REINFORCING CORE COMPETENCES AND ENHANCING INTERDISCIPLINARY RESEARCH"

Commentary by Pascale Ehrenfreund,
Chair of the DLR Executive Board

Image : DLR/Gesine Born

Pascale Ehrenfreund

When I started my position as Chair of the Executive Board, I set myself the goal of leading the German Aerospace Center (DLR) into the future with a new strategy. This objective has been achieved. During its meeting on 28 June 2017, the DLR Senate approved the 'DLR Strategy 2030' and the founding of seven new DLR institutes. The new strategy aims to strengthen DLR's core competencies and exploit internal synergy potentials in an even more targeted way in order to further develop DLR's leading position in research for the benefit of society and the economy.

With 10 new interdisciplinary, cross-sectional projects, DLR will generate technological and societal added value that extends beyond its existing research areas. In addition, together with industrial partners – particularly small and medium-sized enterprises – DLR will be investing in carefully chosen innovation projects. With this strategic development, DLR is working more than ever on solutions to cope with current global challenges and making contributions to Germany as a centre of innovation.

We will continue to provide pioneering services in the key research areas of aeronautics, space, energy and transport. The traditional strength of DLR is its system competence in aerospace research, which we are continuously extending. In energy and transport research, we are working on key topics that are of significance for the 'Energiewende' (Energy Transition) and future transport policies. Across all subjects, our experts are working in national and international networks. We are strengthening our cross-disciplinary security research area to provide practical solutions for future threat scenarios. The 'DLR Strategy 2030' is also establishing a new cross-disciplinary research area for specific topics related to digitalisation. In this way, we are addressing the digital revolution.

DLR's research portfolio is being expanded with seven new institutes. The organisation's research topics and cross-disciplinary areas will benefit from the expertise in the new institutes, and we will be strengthening DLR's system competences. With the new institutes in Hamburg, Dresden and Augsburg, we are expanding the digitalisation of aeronautics research at DLR; in Jena, we are extending investigations in the areas of 'Big' and 'Smart' data – both in space research and beyond. In Oldenburg, we are strengthening research into networked energy systems, while maritime safety is the focus in Bremerhaven.

We are building the new institutes in cooperation with their home states, and are collaborating with local and regional research networks at the various locations. The new institutes are a central component of the new DLR strategy.

FASTER HELICOPTER THANKS TO DOUBLE-DECKER DESIGN

DLR supplies key components for RACER

Image: Airbus Helicopters-PAD

The new helicopter demonstrator from Airbus Helicopters flies at up to 400 kilometres per hour – also thanks to DLR's research.

The high-speed helicopter RACER (Rapid and Cost-Effective Rotorcraft) will fly at more than 400 kilometres per hour. DLR is involved in the aerodynamic design of the wings and the tail plane.

To minimise noise emissions, DLR researchers have analysed the acoustic properties of the new helicopter configuration, which in addition to the main rotor also has two small, so-called box-wings with extra rotors. The technology demonstrator is part of the Clean Sky 2 European aeronautics research programme.

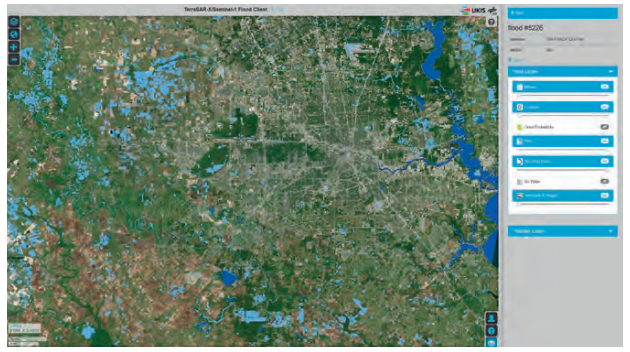
The RACER demonstrator combines safety and cost-efficiency. An innovative 'box-wing' design, optimised for aerodynamic efficiency, will help lift in cruise mode while isolating on-ground passengers from the 'pusher' lateral rotors designed to generate thrust in forward flight. This flexible concept will demonstrate its suitability for a wide spectrum of missions, where increased speed and efficiency will bring significant added value for citizens and operators. This is especially the case for emergency medical services and search and rescue operations, as well as for public services, commercial air transport and private and business aviation.

Drawing upon the characteristic double-decker concept, DLR created various wing designs. Of these, suitable designs were selected and further optimised in close collaboration with Airbus Helicopters. The final design fulfils all requirements and, in particular, will enable the RACER to attain exceptional flight performance over the entire flight range while maintaining low fuel consumption. The aerodynamic improvements for the tail boom focused on the tail plane to ensure good manoeuvrability and stability of the helicopter, in addition to low air resistance. The first flight of the demonstrator is planned for 2020.

DLR PROVIDES SATELLITE DATA FOR HURRICANE HARVEY

German radar satellite TerraSAR-X acquires images of flooded regions

In anticipation of the catastrophic Hurricane Harvey, the International Charter 'Space and Major Disasters' was activated early on the evening of 24 August 2017.



Flood map of Houston area, acquired by TerraSAR-X in August 2017.

This was initiated by the Charter member United States Geological Survey (USGS) on behalf of the Texas Emergency Management Council. DLR provided real-time recordings and archive data from the German radar satellite TerraSAR-X, which enabled a detailed analysis and an overview of the flood situation in Texas. Using these and other satellite data provided by 16 Charter members, the Center for Space Research at the University of Texas was able to provide assistance and information to disaster relief personnel on the ground.

DLR's Earth Observation Center (EOC) delivered the data acquired by the satellite as quickly as possible. The particularly wide swath mode of the TerraSAR-X recordings made it possible to precisely depict the extent of the catastrophe shortly after the hurricane made landfall. A decisive advantage is the weather-independent nature of radar imaging. While optical satellites are limited to imaging cloud surfaces on an overcast day, the radar instrument on the German satellite is able to penetrate cloud cover to 'scan' the surface and receive the reflected 'echo'. Radar satellites are the first choice in large-scale flood disasters, because the backscattered signal from water bodies stands out from non-flooded surfaces.

The flood maps derived from the satellite data help to coordinate emergency procedures – for example to identify particularly affected areas, assess damage to infrastructure and traffic routes, or plan evacuation centres.

Image: DLR/Ernsting

DIGITAL PILOT IN THE COCKPIT

A digital pilot in the cockpit to provide its human colleagues with in-flight advice – that is the idea behind project A-PiMod, which involves DLR and seven partners from science and industry. The newly developed cockpit architecture not only monitors the aircraft and environmental conditions, but also the state of the pilots. The system uses the pilots' eye movements, gestures and operations to draw conclusions about their current intentions, situational awareness and work-related stress. A-PiMod uses this data to provide the pilots with the best possible support in any given situation. For this reason, A-PiMod has been honoured with the German Mobility Award as a lighthouse project for smart mobility.

CUCUMBERS IN THE ANTARCTIC

A model greenhouse for deserts and low-temperature areas will enter long-term testing under Antarctic conditions at the end of 2017. Irrespective of the weather, the Sun and the time of year, the EDEN ISS project will cultivate cucumbers, radishes, peppers, lettuce and herbs with reduced water consumption while avoiding the need for pesticides and insecticides. Aeroponics is the process behind this type of cultivation, which will now enrich the menus of the crews wintering at the Neumayer III Antarctic station operated by the Alfred Wegener Institute (AWI). This technique is used to cultivate plants in a sterile environment without soil by spraying them with a water/nutrient blend. EDEN ISS may also represent a food supply model for a future manned mission to Mars. Numerous international partners are working together in a research consortium under the auspices of DLR to ensure the success of the project. The progress of EDEN ISS can be tracked via its social media accounts on Instagram and Facebook and via the hashtag #MadeInAntarctica.

HALO MEASURES EMISSIONS

Emissions from major cities can spread beyond the limits of these urban areas under certain weather conditions. DLR carried out research flights in July 2017 to find out more about the distribution and conversion of emissions from London, Rome, the Ruhr region and other European urban areas. The HALO research aircraft, equipped with 20 instruments, flew for more than 50 hours to record the various gas and particulate emissions arising from those major cities. Researchers also hope to find out which conversion processes take place that lead to secondary photooxidants and aerosol particles. They investigated, for example, the formation of ozone from nitrogen oxides, hydrocarbons, particles of sulphur dioxide and organic precursor compounds. In parallel with the HALO flights, measurements using other aircraft are also taking place in Britain and Italy. Furthermore, ground-based measurements and laser-based lidar observations are being used across Europe for planning and assessing the HALO flights.

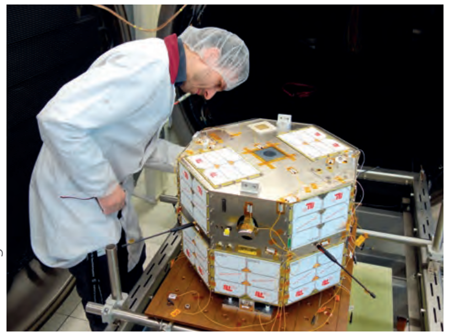
NEW OIL FOR SOLAR POWER PLANTS

Heat-transfer oils can make parabolic reflector power plants more worthwhile. DLR is heading a consortium of research and industry partners that is working to improve the oils used in absorber tubes. At present, the functional use of a silicone oil developed by Wacker Chemie AG is being tested at temperatures of up to 425 degrees Celsius. This new heat-transfer medium is more flexible, particularly in the lower temperature range: Its solidification point is minus 55 degrees Celsius, which would render heating systems unnecessary to protect the heat-transfer fluid from freezing, even at cold outside temperatures. As opposed to organic mixtures, which are commonly used, silicone-based heat-transfer oils show better ageing properties and suffer less from the undesirable side effect of hydrogen formation. Silicone oil also does not release any hazardous substances such as benzene, which makes the operation of solar parabolic trough power plants more environmentally friendly and safer.

TWO NEW MINISATS IN SPACE

Since 14 July 2017, two new German mini-satellites have been in orbit, namely the 'Flying Laptop' and the 'TechnoSat'. As well as testing new technologies under space conditions, the small satellites funded by the DLR Space Administration are also educational training missions. Seven experimental payloads are installed on the almost 20-kilogram octagonal TechnoSat nanosatellite, whose function and performance will be tested in orbit. In addition to a large clean room for the integration of satellites, an optics laboratory and a thermal-vacuum chamber, the ground station with a control segment at the University of Stuttgart was also set up and a satellite simulation environment was developed. The satellite platform itself has a system for high-precision attitude control and three solar panels featuring an innovative unfolding mechanism. In addition, it features other novel systems for on-board testing in space.

Image: Technische Universität Berlin



MEET DLR AT ...

INTERNATIONAL ASTRONAUTICAL CONGRESS
25 - 29 September 2017 • Adelaide, Australia
Founded in 1951 to foster the dialogue between scientists around the world and support international cooperation in all space-related activities, the IAC connects space people from all over the world, including DLR as organiser. The International Astronautical Federation is the world leading space advocacy body with 300 members, including all key space agencies, companies and institutes across over 60 countries. This year's IAC is being hosted by the Space Industry Association of Australia. The main theme of the 68th IAC edition is: 'Unlocking imagination, fostering innovation, strengthening security'.

E^2FLIGHT SYMPOSIUM
5 - 6 October 2017 • Stuttgart, Germany
This year's E^2Flight Symposium will be held at the Mövenpick Hotel Stuttgart Airport & Messe. The focus will be on new aspects of electric flight, like the feasibility and the scientific aspects of this new and promising technology. The symposium's target audience is engineers and researchers from universities, research centers, and from industry, as well as research groups and certification authorities that have a connection with, or an interest in electric powered aircraft. Registration is required in order to participate.

SPACE TECH EXPO EUROPE 2017
24 - 26 October 2017 • Bremen, Germany
Space Tech Expo Europe is Europe's premier B2B Space engineering event for spacecraft, satellite, launch vehicle and space related technologies and is attended by thousands of industry leaders, decision makers, engineers, specifiers and buyers to meet manufacturers and the supply chain for civil, military and commercial space. The event will be held in Bremen, a city of aerospace excellence. DLR will be displaying exhibits from Technology Marketing and the Space Administration at its stand in hall 5 (stand H20).

UN CONFERENCE ON INTERNATIONAL COOPERATION TOWARDS LOW-EMISSION AND RESILIENT SOCIETIES
22 - 24 November 2017 • Bonn, Germany
Organised by the United Nations Office for Outer Space Affairs (UNOOSA), DLR and the German Federal Ministry for Economic Affairs and Energy (BMWi), this conference will bring together experts from the space and the development community as well as decision makers, researchers and practitioners to discuss and work out recommendations considering 'International cooperation towards low-emission and resilient societies' as a way to provide input to the UNISPACE+50 process.

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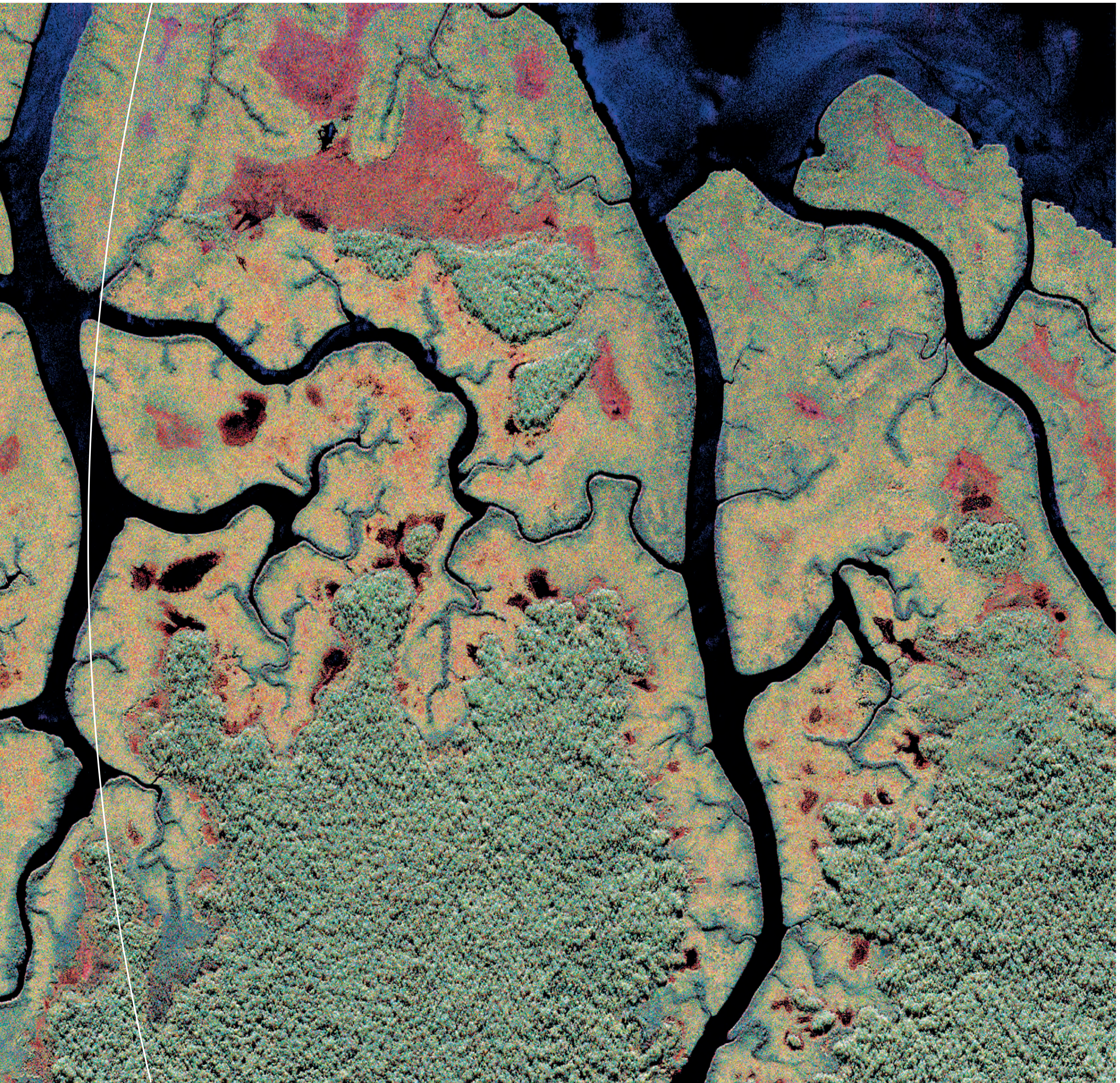
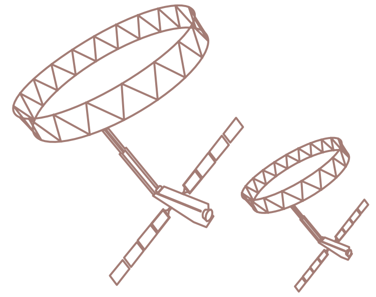


Mangrove forests in an estuary into the Atlantic Ocean south of Libreville, the capital city of Gabon. The radar image in the L band was acquired in 2016 as part of a large-scale aircraft campaign under contract to the European Space Agency (ESA) in cooperation with the French, United States and Gabonese space agencies. The aim was to determine forest biomass and three-dimensional forest structure from tomographic radar images.

LISTENING TO EARTH'S HEARTBEAT



Greater insight into climate research with the Tandem-L satellite mission

By Elisabeth Schreier

The Earth system is multifaceted, complex and in constant motion. Our home planet is ever changing – the ground rises and falls, glaciers calve into the ocean, and fires destroy forest areas. "But alterations to the environment are not only natural – today, human intrusion is playing a major role too – from deforestation and construction activities through to the impact we have on the climate," says Alberto Moreira, Director of the Microwaves and Radar Institute of the German Aerospace Center (DLR) and Principal Investigator of the Helmholtz Alliance 'Remote Sensing and Earth System Dynamics'. Understanding these changes is an essential part of climate research and is important for enabling sustainable, positive development in the long term. Since the 1990s, Moreira has been working on radar technologies that enable Earth's dynamics to be recorded and depicted globally. The Tandem-L mission will bring science one step closer to achieving this goal.

Earth observation using radar satellites offers unique insights into our planet's dynamic processes. Radar satellites deliver reliable data regardless of weather and time of day, and enable the use of highly precise interferometric and even tomographic measurement techniques. A recent example is the interferometric imaging of Earth provided by the twin satellites TerraSAR-X and TanDEM-X, which since 2010 have been measuring the Earth´s surface in close formation flight at a few hundred metres apart. Numerous fields within climate and environmental research are benefiting from the highly precise, three-dimensional images of our planet. Although more than 1000 scientists across the globe are working with the elevation model of Earth, it quickly became clear that TanDEM-X is merely scratching the surface – quite literally – of what such a satellite mission is capable of.

Numerous processes important to environmental research are occurring within the three-dimensional structure of forest ecosystems. In addition, many of the changes take place within a relatively short period of time, which is why it is necessary to continuously monitor their status. Consequently, a solution was needed that could not only penetrate deeper into the vegetation layer but also enable regular imaging at short time intervals. "We carried out the first experiments in X band and L band using our airborne radar system in the early 1990s, and realised how accurately we could determine the Earth's topography with radar. And so, the idea of TerraSAR-X and TanDEM-X was conceived. When TanDEM-X was officially approved in 2006, the question of how it could be developed further immediately arose at the Institute. My answer to this – even back then – was very clear: the next project will be Tandem-L," recalls Moreira.

Image: CC0 Public Domain

Hydrosphere

WEATHER FORECASTING AND WATER MANAGEMENT

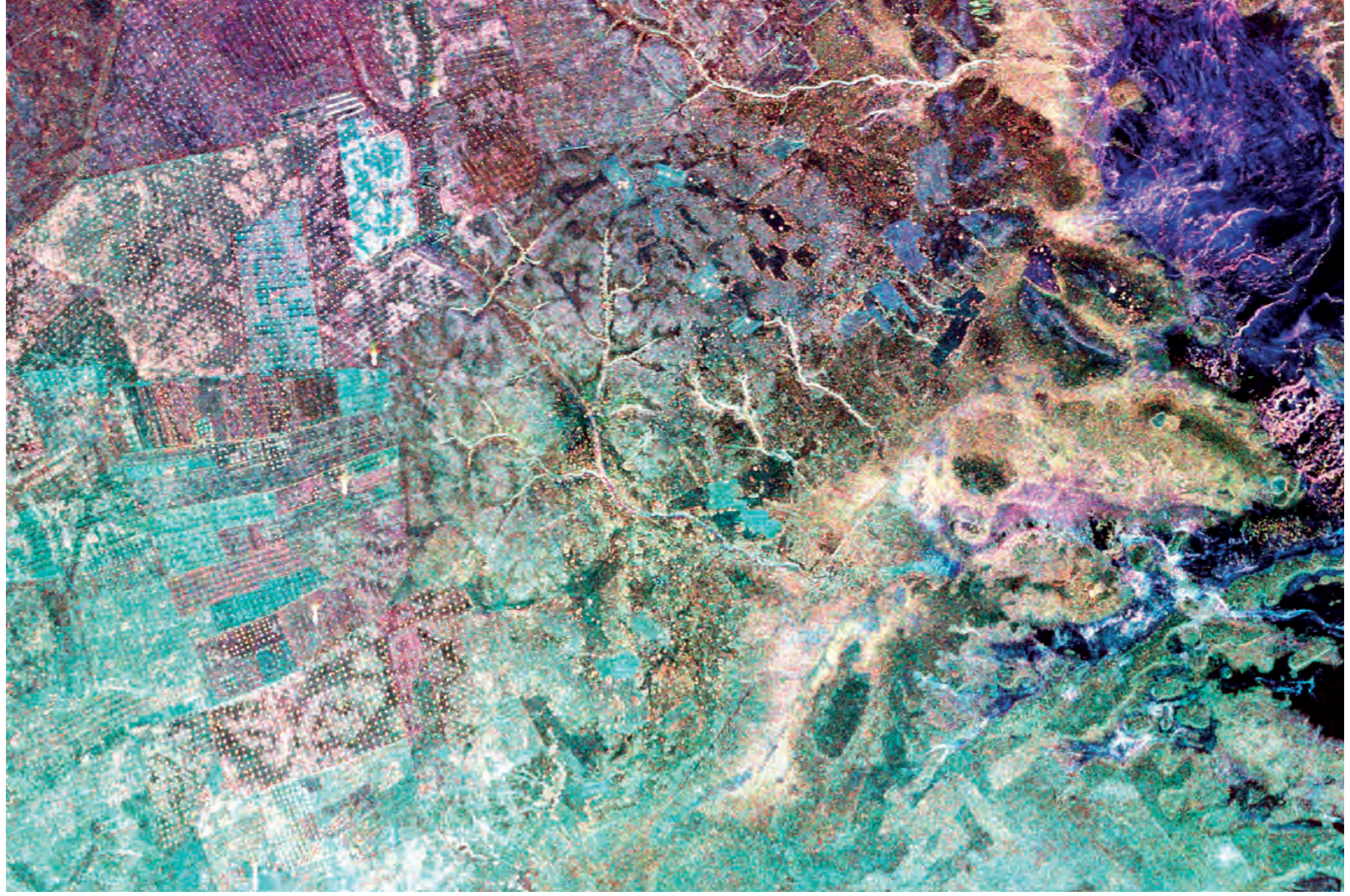
Carsten Montzka,
Jülich Research Centre

Exchange processes involving water and energy take place on Earth's surface. These processes drive mass movements both in the lower atmosphere and in the soil. Tandem-L will be able to observe such processes directly and indirectly via changes in the soil moisture, and it will do so with previously unattained spatial resolution and precision. Tandem-L has been conceived as a monitoring mission. The high temporal repetition rate, combined with improved resolution and precision, will open up new areas of application for satellite remote sensing.

A whole range of important exchange processes on the surface are barely taken into consideration in current weather forecasting models – and sometimes not at all. Developing these models at a regional or even local level is still exposing a data gap that can be filled with Tandem-L. Integrating Tandem-L information on soil moisture into numerical weather prediction models will improve weather forecasting significantly. The regional management of water resources can also benefit from Tandem-L. Large-scale monitoring of soil moisture is important for the management of reservoirs or for optimal irrigation in agriculture.

Yet Tandem-L will provide important information not only for the hydrology of land surfaces, but also about the ocean surface. Using SAR along-track interferometry, it is even possible to determine the velocity of ocean currents near the surface. All in all, the possibilities offered by Tandem-L are quite varied and offer great potential for science.

Image: Forschungszentrum Jülich

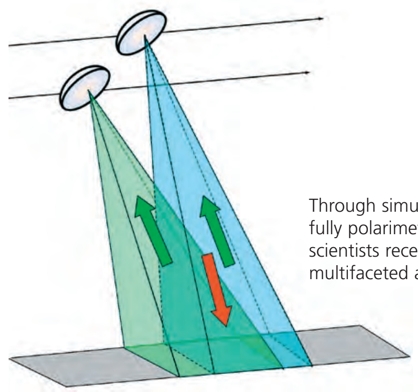


Olive groves southwest of Ben Gardane, Tunisia. The image (about 2000 metres by 1500 metres) was acquired to support ESA's Aquifer project, which serves to examine and manage groundwater reserves in Africa using remote sensing, as part of the UN's TIGER initiative (Earth Observation for Integrated Water Resources Management (IWRM) in Africa). The colour of sand (yellow-brown tones) dominates optical images of this region. However, the radar image appears unusually colourful. The colours come from a combination of three radar images (RGB), each of which shows radar backscattering at different polarised L-band waves. The individual olive trees, neatly arranged in groves, are easy to see. As long waves can penetrate dry, sandy terrain, in addition to the reflections from the surface, one can also see structures hidden beneath. Fractal shapes can therefore indicate subterranean water veins, and patched areas can even indicate water deposits.

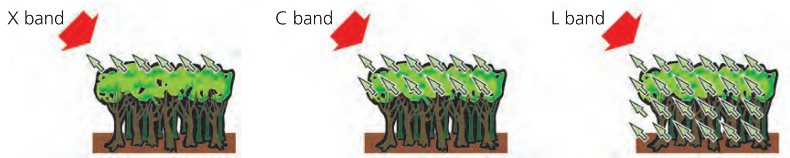
From vegetation to plate tectonics – innovative technology with great potential

Similarly to TanDEM-X, Tandem-L will consist of two identical satellites orbiting Earth in helical formation flight and scanning the surface by radar, swath after swath. Radar systems are usually operated at various frequencies between three centimetres (X band) and 25 centimetres (L band). The X-band waves used for TanDEM-X are short and are already reflected by the tree canopies. The longer L-band waves, which will be used for Tandem-L, can penetrate much deeper into vegetation, ice or soil. Hence, it will be possible to measure the entire biomass – from the tree canopy to the forest floor. Two different operating modes are used for this. Firstly, there are 3D measurements based on polarimetric SAR interferometry (Pol-InSAR). The combination of interferometry (the superimposition of the radar waves) and polarisation (the vertical and horizontal alignment of the waves' oscillation) enables clear conclusions to be drawn with respect to the type of vegetation, as well as its density and structure. Secondly, in deformation mode it is possible to measure topographical changes – tectonic shifts, volcanic activity or landslides. “The two modes can be operated alternately, as required. For the operation of the satellite, there will be an observation plan based on the requests of the participating scientists in the Helmholtz Alliance,” Moreira explains.

A particular innovation in the satellite design is the circular foldable 15-metre diameter reflector antenna. Thanks to its large surface area, up to 350-kilometre-wide swaths can be imaged. To maintain high resolution even at this large swath width, Tandem-L uses the DLR-developed concept of digital beamforming. This technology takes advantage of the fact that the echoes reflected back from the surface of the Earth are received by the satellite in temporal sequences. In the so-called digital feed array, individual antenna elements are combined in such a way that a tightly bundled antenna diagram precisely follows these temporally displaced signals. As a result, despite its 350-kilometre-wide coverage, Tandem-L can guarantee a resolution down to five metres. While it takes TanDEM-X approximately one year to record the Earth's entire surface, Tandem-L will be able to do this up to twice a week. Changes on Earth that occur within a very short time can therefore be recorded.



Through simultaneous data acquisition using two fully polarimetric radar satellites in the L band, scientists receive unique data products for multifaceted applications.



Comparison of the penetration depths in vegetation of X, C and L bands with wavelengths of three, five and 24 centimetres: While radar waves in X band are only reflected by the upper tree canopy, L band reaches the ground. Only L-band radar systems can receive signals from every part of the vegetation.

Image: CC-by-sa Christian Ziegler/Wikipedia.de

Biosphere

BETTER INFORMATION ON FORESTS

Andreas Huth,
Helmholtz Centre for Environmental Research, Leipzig

Earth's forests store huge quantities of carbon. As such, they play a critical role in the global carbon cycle and are important for the global climate. But in the last two centuries, our planet's forest area has been halved as a result of human land use. Due to the heterogeneous and multifaceted structure of the forests, it is only possible to determine their condition to a limited extent at the moment. The Intergovernmental Panel on Climate Change (IPCC) stresses the need for programmes to measure forest biomass – and changes to it – on a global scale. Yet national forest inventories are based on estimates produced from local inventory plots. In the tropics, often disturbed forest areas are not necessarily considered. The next generation of high-resolution radar satellites, such as Tandem-L, can fill these knowledge gaps. An important objective of the Tandem-L mission is to determine forest biomass globally and its changes over time. Using data on forest height and structure, biomass can be estimated with much greater accuracy. Important structural characteristics here are tree density and vertical heterogeneity.

In this respect, the L band stands out in comparison with the X and C bands due to its penetration depth into vegetation. This new technology enables scanning forests all the way to the forest floor – even in dense vegetation. In addition to information on the forest structure, knowledge of soil moisture and the level of disturbance in the forest can also be derived. By linking information from radar remote sensing with forest simulation models, researchers can derive important forest properties at a large scale, also thanks to the high spatial resolution.

Such approaches – meaning the combination of forest inventories with radar measurements and forest modelling – are currently being tested at a newly established super test site in Froscham (Traunstein, Bavaria). In the 25-hectare forest area, 16,000 trees have been analysed and flights involving both radar and lidar have been carried out. The acquired data will be freely available and the forest plot will become part of the international ForestGeo network. Findings from this and other campaigns, for example AfriSAR in Gabon, provide a better understanding of the connection between forest biomass, forest structure and carbon flows.

Image: UFZ

Image: CC0 Public Domain

Geosphere

CAPTURING EARTH'S MOVEMENTS

Mahdi Motagh,
German Research Centre for Geosciences (GFZ)

Tandem-L not only underlines the power of innovation and the leading role of German space technology, but also offers unique opportunities to carry out precise and reliable geodetic measurements from space. Researchers will have the opportunity to, for the first time, measure geological or man-made deformations on a global scale, systematically and over large areas, all with high resolution (down to one metre) and greatly improved temporal coherence. This is possible thanks to the long wavelengths of the L band, which make Tandem-L impervious to measurement errors caused by structural changes and/or massive deformations, and superior to other existing Synthetic Aperture Radar (SAR) missions.

We will receive updated information on the topography down to the millimetre range on a weekly basis. With this, we can track diverse geological processes accurately – whether they are tectonic movements and fault-zone deformations, magmatic processes in volcanoes, mass movement or erosion processes. Other processes caused by humans can also be documented, such as deformations triggered by underground liquid injection or extraction. We can also draw conclusions on the stability of dams, among other things.

Unlike standard radar systems, Tandem-L will not simply measure one component of the three dimensional deformation field – by using a combination of different observation geometries, it will enable 3D movement vectors to be reconstructed. But more than this: for emergency purposes, such as an earthquake or a volcanic eruption, the affected area can be placed under observation within a day or two. This makes Tandem-L a completely new player in the rapid provision of data from space. The information on destroyed or endangered areas will advance research and also be useful to the public.

Image: GFZ

Detailed global information for science and policy

"The focus of the Tandem-L mission is different from that of previous missions: TanDEM-X targets the commercial and security technology sector, whereas Tandem-L is a high-calibre science mission," says Richard Bamler, director of DLR's Remote Sensing Technology Institute, which is developing methods for processing the vast quantities of data. "From the outset, Tandem-L has been tailored to the requirements of the scientists, and not just restricted to commercial interests. Naturally, the data are also of relevance to companies."

When planning for the L-band mission began after the successful launch of TanDEM-X, DLR brought additional partners of the Helmholtz Association of German Research Centres (Helmholtz-Gemeinschaft Deutscher Forschungszentren; HGF) to the table. The Helmholtz Alliance 'Remote Sensing and Earth System Dynamics' was founded under the aegis of DLR in 2012 – one year after initial ideas were laid out. Some 140 scientists are now working in the Alliance, meeting regularly to exchange information. Specific research focal points were defined in the areas of the geo-, hydro-, cryo- and biosphere, and these alone already cover seven of the essential climate variables, which include sea-ice coverage, soil moisture and forest biomass. The climate variables defined by the Global Climate Observing System (GCOS) provide information about the Earth system and changes in the climate. "Scientists who, for example, provide data for the IPCC (Intergovernmental Panel on Climate Change) report will be able to use Tandem-L data for their work," explains Bamler. "Another example is the measurement of biomass. This is very important for the climate agreement in connection with global carbon dioxide emissions. Countries want to know, of course, the amount of carbon bound by their ecosystems. To determine this, one must first establish how much biomass – in forests, for example – is available to act as a carbon sink. And this requires regular monitoring."

A decisive year met with great anticipation

2017 has been a very exciting year for Moreira and his colleagues so far. In January 2016, the Tandem-L team submitted a proposal to the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung; BMBF) for a large-scale research infrastructure. "The project went through a review process by the German Council of Science and Humanities. In addition to scientific excellence, commercial viability was also examined," the radar expert explains. "In July 2017 Tandem-L, together with 10 other proposals, was selected for the final step – the research- and social-policy evaluation. We expect a final decision regarding the implementation of Tandem-L by March 2018."

The conception and design of the new radar mission benefits from DLR's experience with the TanDEM-X mission, which has been in orbit for seven years. The Tandem-L mission will be operated from the DLR site in Oberpfaffenhofen, where some 100 employees from four DLR institutes – the Microwaves and Radar Institute, the Remote Sensing Technology Institute, the German Remote Sensing Data Center (Deutsche Fernerkundungsdatenzentrum; DFD) and Space Operations – are working closely together and, in doing so, are controlling the entire system chain for the mission. Both Moreira and Bamler emphasise that this is the great strength of the Tandem-L project – no one else can offer this.

Launch in late 2022 following green light

If Tandem-L gets the go-ahead and the funds are approved, the rocket carrying the two satellites, which are designed for a mission duration of 10 years, could launch in 2022. The geoscientific information that the mission will yield may well spark many scientific findings for several years after the mission ends. "Tandem-L is designed to serve a wide range of applications," Bamler says. "It will not always provide the solution by itself – sometimes additional information will be needed. Yet Tandem-L comes fantastically close to the ideal, providing standalone, informative data on each technical issue."

In a time of fast-paced change and in which science – as well as policy – depends on reliable information, a mission aimed specifically at climate research is of great significance. "What drives us is the vision of knowing what is changing on our planet – at any time," says Moreira. "Tandem-L is just the answer to a radar mission designed specifically for climate research and environmental monitoring."

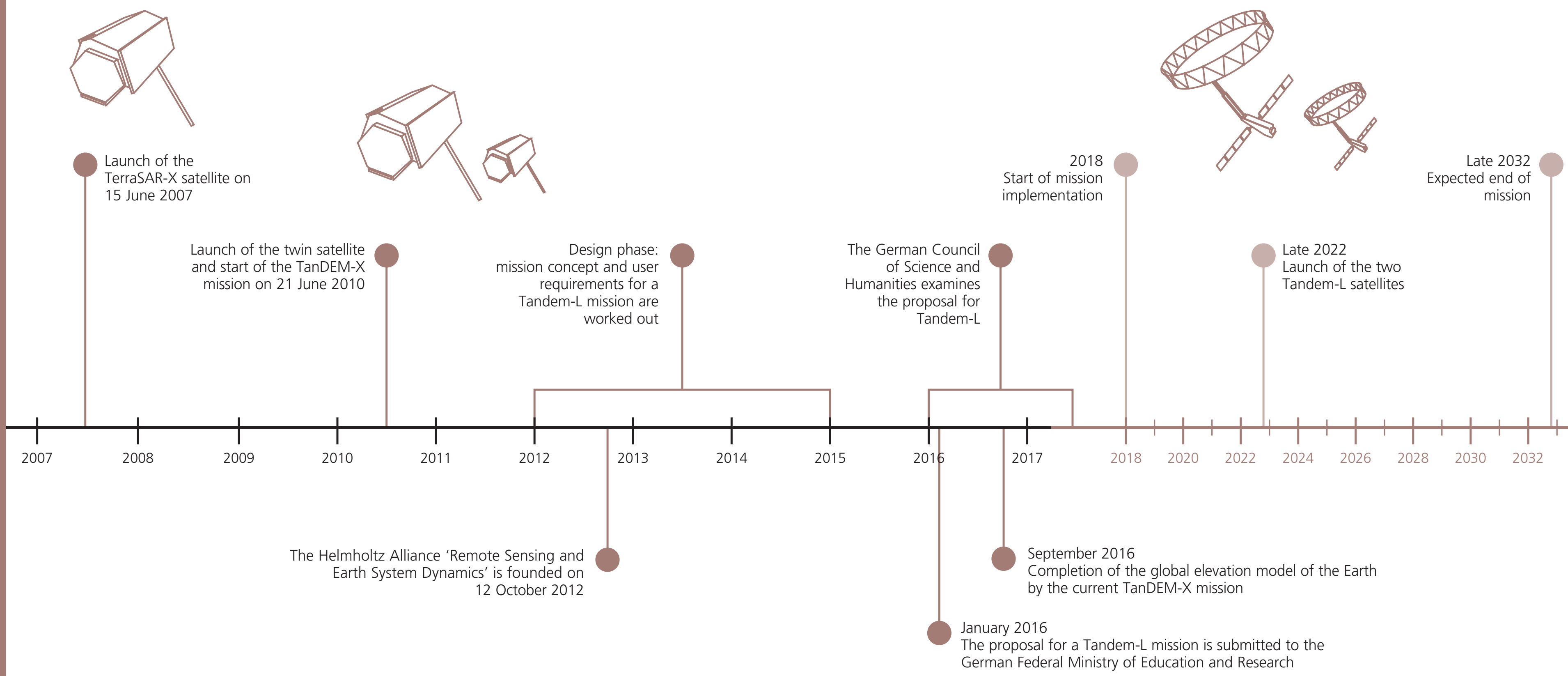


Image: CC0 Public Domain

Cryosphere

INCREASE IN KNOWLEDGE OF ICE SHEETS

Angelika Humbert,
Alfred Wegener Institute, Bremerhaven

Tandem-L will, for the first time, give us the opportunity to use SAR tomography to analyse the structure of the topmost 100 metres of the ice sheets in Greenland and Antarctica in high spatial resolution and with complete coverage – a gigantic step for glaciologists! Layers in the firn that occur as a result of the seasonal compaction of snow will finally be observed on a large scale. The Tandem-L mission therefore latches directly onto the signal of climate change, and I expect it to provide an enormous increase in knowledge of spatial changes in the ice sheets.

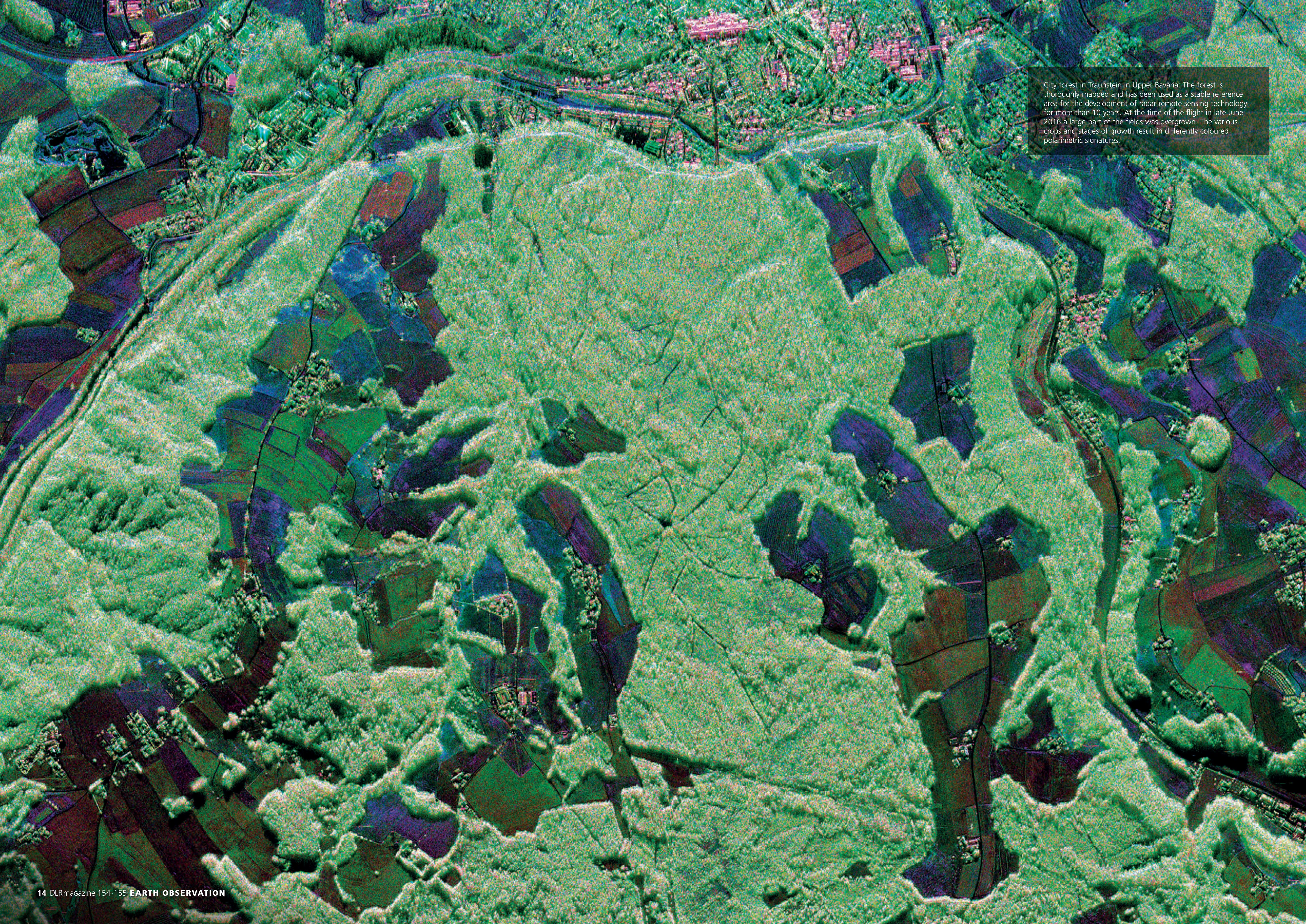
Image: MBuchholz

HELMHOLTZ | ASSOCIATION

HELMHOLTZ ALLIANCE 'REMOTE SENSING AND EARTH SYSTEM DYNAMICS'

For several years, the Helmholtz Association (Helmholtz-Gemeinschaft; HGF), in which major German research institutions – including DLR – come together, has been promoting what are known as Helmholtz Alliances. HGF members can ally themselves with partners from science and research to address new topics or advance current research projects.

In 2012, DLR founded the Helmholtz Alliance 'Remote Sensing and Earth System Dynamics' together with nine other Helmholtz centres and another 18 partners. The aim is to generate new geoinformation products using Earth observation satellites. These information products are expected to help improve our understanding of the multilayered Earth system and the processes at work within it.



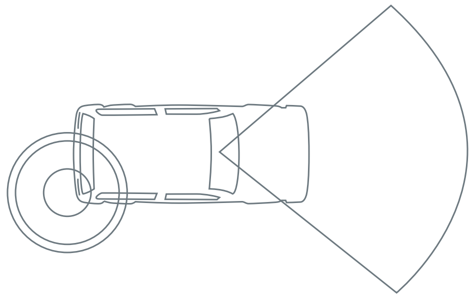
City forest in Traunstein in Upper Bavaria: The forest is thoroughly mapped and has been used as a stable reference area for the development of radar remote sensing technology for more than 10 years. At the time of the flight in late June 2016 a large part of the fields was overgrown. The various crops and stages of growth result in differently coloured polarimetric signatures.

Image: chombosan/Fotolia

DRIVING TOWARDS AUTOMATION

Vehicle automation has triggered a major shift in human mobility. Yet many technological hurdles must be overcome before autonomous vehicles can drive safely. This issue also extends far beyond the technical aspects. Social and ethical questions must be addressed, and policies revised. Thanks to its broad research spectrum, DLR is able to provide important answers and recommend actions to policy makers and commercial enterprises. DLR's areas of expertise range from intelligent vehicle technologies and innovative test facilities for vehicle developers through to analyses relating to the mobility behaviour of the future and the consequences for traffic planning and public transport.

An overview
compiled by DLR transport editor Dorothee Bürkle



Reinventing mobility through intelligent cars

By Karsten Lemmer, DLR Executive Board member responsible for energy and transport research

Karsten Lemmer

Reading through the first emails of the day while on the way to work, and no longer having to worry about rush-hour traffic as on-board computers, sensors and GPS safely take control – autonomous cars are no longer a dream. Even today, vehicles can relieve the driver of parking manoeuvres, and, in a few years, drivers on motorways will be able to take their hands off the steering wheel, at least for a while. In the future, we will order a car using an app, and it will take us to our destination before moving on to the next user. Having to refuel, park and clean the car ourselves will be a thing of the past. Autonomous and highly automated driving in a networked world will fundamentally transform our mobility – but how will our mobility patterns change as a result? What will vehicles of the future look like? Will driving be safer? What new risks might arise?

One thing is certain – we will need to understand and master an enormously complex environment for highly automated driving, especially in urban traffic, where everything from pedestrians and cyclists to rolling footballs must be safely identified. At the moment, technology lacks the 'sixth sense' that allows humans to anticipate the outcome of a given situation. In this respect, there is an enormous need for research and development efforts to enable vehicles to automatically handle these complex situations.

Fields of action for research

A major hope is that automated driving will be safer – and rightly so, as many accidents are a result of human error. But there is no such thing as 100 percent safe technology. For this reason, guidelines and action plans for ethical and legal issues regarding security and data protection are already being defined. Who is responsible in the event of an accident? What data should and may be stored in order to determine this? And not least, how should and what can technology evaluate and decide – if at all?

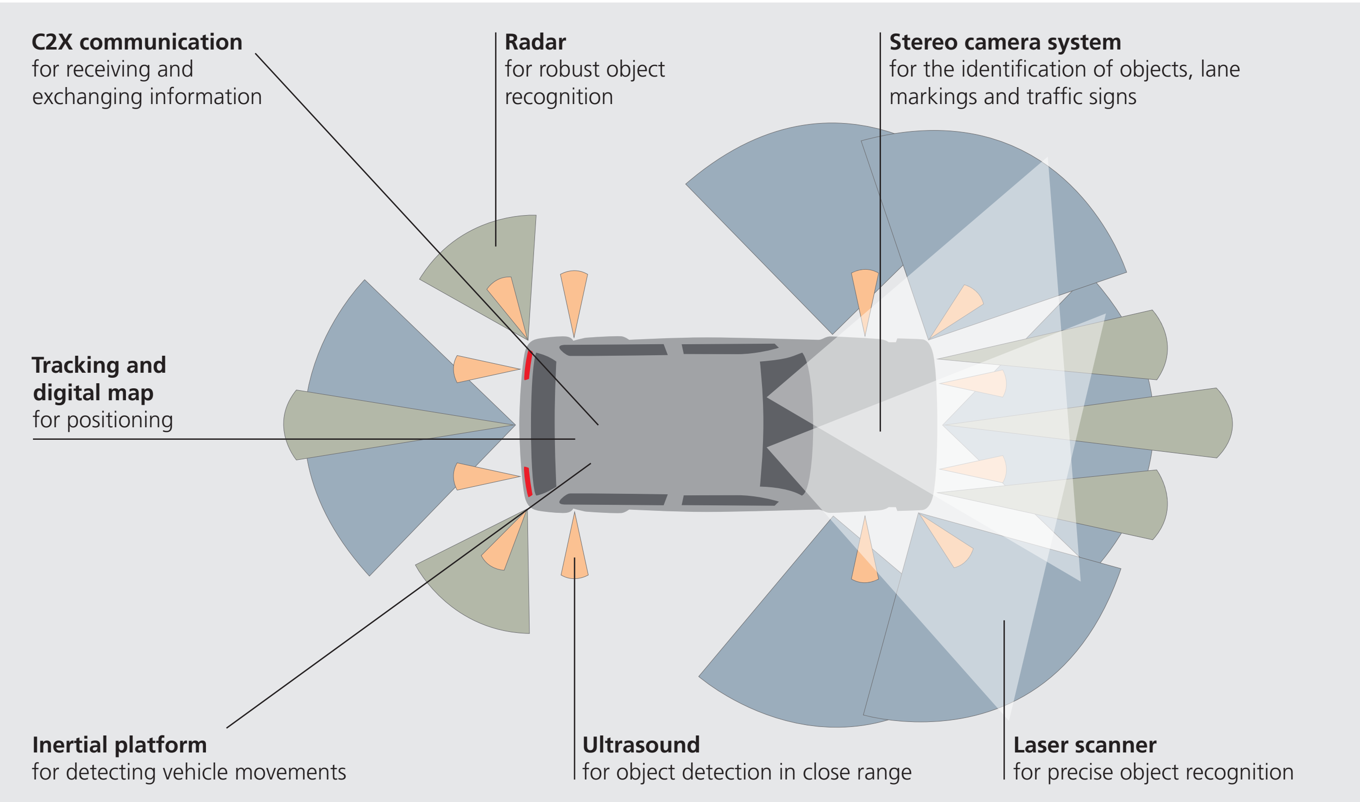
The acceptance of such systems will play a role in the introduction of automated vehicles. There will be drivers that feel powerless when the vehicle takes control. It will also be necessary to explore drivers' reactions in mixed traffic when automated vehicles behave strangely more reasonably than humans. Another focus of DLR research is the safe handover of control between the vehicle and the driver.

Paradigm shifts for the automotive industry

In times of digitalisation, vehicle manufacturers face the enormous challenge of viewing mobility no longer as a car, but rather as a service. At the same time, keeping pace with the development of new, environment-friendly engines requires a reorientation of previous vehicle concepts. In order to survive, it is crucial that car manufacturers and suppliers reposition themselves for the two paradigm shifts.

Transport researchers at DLR have the task of developing solutions for safe, efficient and environment-friendly mobility, and to assess them from a variety of perspectives. With the Application Platform for Intelligent Mobility (AIM) in the Braunschweig urban area, DLR already has a platform for developing and testing automated, networked vehicles – both under realistic conditions and in simulations. The test site in Lower Saxony will greatly enhance their capabilities for investigating automated vehicles on motorways and major roads. DLR is researching assistance and automation systems for future generations of intelligent vehicles from a variety of perspectives. These include the effects on passenger and commercial transport, as well as on urban development and entirely new, more user-friendly mobility options. With this broad, systematic array of topics, DLR is supporting government, industry and local authorities on the road to automated, digital mobility.

Schematic representation of the sensors in an automated vehicle



On the road to intelligent vehicles

By Frank Köster

Automation and networking are increasingly shaping our transport system. Vehicles will be able to 'see' via laser scanners, radar sensors and cameras. They will continuously monitor their position with sufficient accuracy and combine this with appropriate virtual images of the world around them. Using various communication technologies, they will exchange data and information with one another, as well as the transport infrastructure and back-end support systems. Complex algorithms will enable the vehicles to understand their environment and to react to situations in a targeted and possibly even cooperative manner, so that they can be integrated into the overall transport system in a safe, energy-efficient and user-friendly way.

Concomitant with this is the fact that the traditional role of the driver will be largely replaced by technology in automated, networked vehicles, but people's desire to determine their own mobility will remain unchanged – the driver will continue to want to have control of the vehicle. Manual driving will still exist in the coming years, because in many of today's concepts and product ideas, humans will continue to be an important backup option for automated, networked road vehicles in the event that the technology 'is at a loss' or is not functioning properly.

The importance of testing cooperation

As part of the Next Generation Car (NGC) meta-project and in the research areas of vehicle intelligence and mechatronic chassis systems, DLR is working on concepts and technologies for intelligent road vehicles, as well as tailor-made development and testing methods. In addition to developing innovative vehicle functions for driving on the motorway, DLR researchers in Braunschweig and Berlin are also working on options for automated driving in cities and municipalities. The methods required for designing the vehicles have been an integral part of research and development work at DLR for several years. The Application Platform for Intelligent Mobility (AIM) and the test site in Lower Saxony are important infrastructures for this.

VEHICLE INTELLIGENCE AND MECHATRONIC CHASSIS SYSTEMS

- System architecture
- Sensors
- Sensor data fusion
- Situation representation
- Human factors
- Automated, networked vehicle functions
- Mechatronic chassis systems
- Development and testing of advanced vehicle functions
- High-precision virtual worlds
- Next Generation Car
- Vehicle Concepts
- Vehicle structures
- Drive train
- Energy management

Participating institutes: In addition to DLR's three core institutes in the transport sector (Transportation Systems, Vehicle Concepts, and Transport Research), various institutes from the aeronautics, space and energy sectors are involved.

The work carried out in relation to vehicle intelligence is enhanced by activities in numerous national and international research and development projects, with the result that DLR is continuously expanding its know-how in the area of automated, networked driving.

DLR researchers are testing automated vehicle functions with the FASCar test vehicle

Cooperative vehicle functions are at the heart of automated and networked driving in the city. For example, DLR research vehicles in Braunschweig can drive autonomously on certain stretches of road. They adjust their speed to that of the preceding vehicle; communicate with traffic lights and background traffic management systems; react appropriately to speed restrictions; and comply with existing traffic regulations. Today, every relevant driving situation relating to linear guidance in the city can be managed automatically by the system. Lane changes and appropriate behaviour, for example at intersections, will complement the spectrum.

How capable are humans?

To achieve this, the results of various scientific areas of work must be brought together in the DLR research vehicles. A key point for this development is a technology platform for the technical integration of the different subsystems in an automated, networked road vehicle – a powerful system architecture. Thus, data from different sensors must be combined in order to reliably assess a situation. In addition, many issues regarding the integration of artificial intelligence (AI) approaches into automated, networked road vehicles have still not been satisfactorily resolved. The human/user is also an important object of study in the context of automated, networked driving. For example, functional design requires a precise understanding of human performance ability. The interaction between automated vehicles and other road users needs to be demonstrated. And the direct integration of humans in vehicle guidance – in terms of a fall-back option – is another vital area of work. For we should not forget: the driver is only human.

Driving forward automated and networked vehicles in Lower Saxony

By Frank Köster

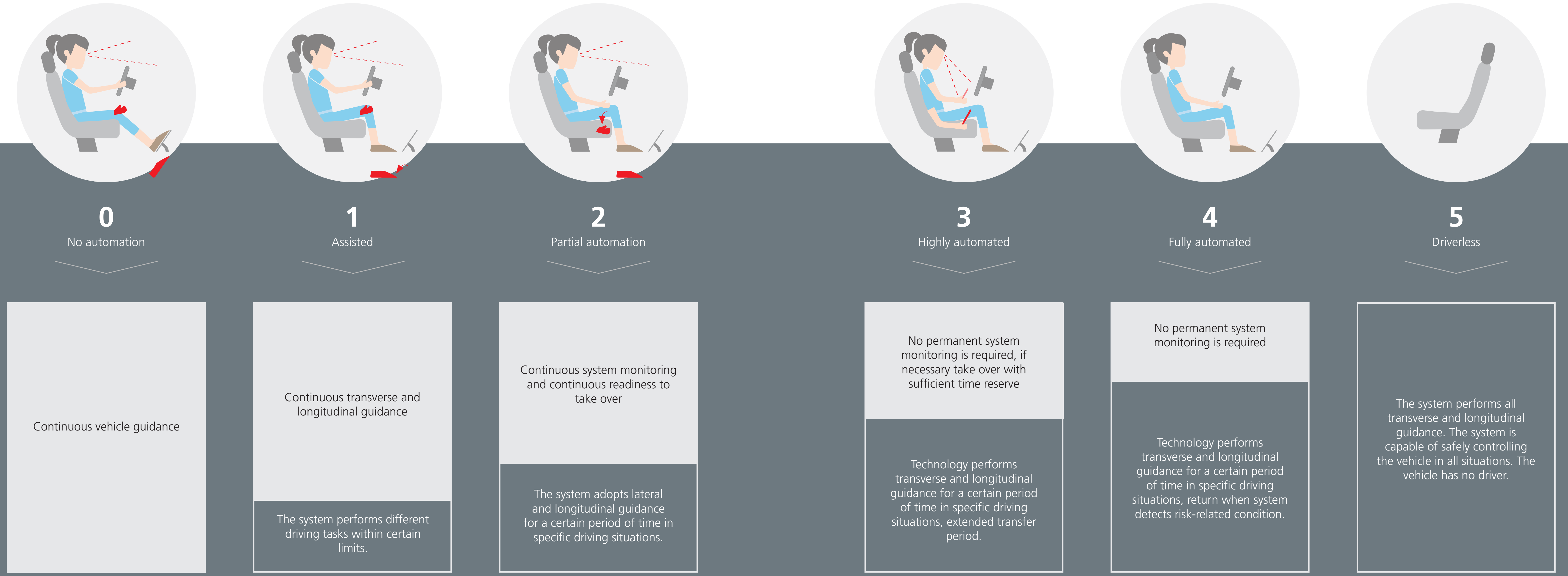
A real test laboratory for automated, networked vehicles is currently being constructed on a 280-kilometre stretch of motorway in Lower Saxony. From 2019, test vehicles will move amidst the regular motorway traffic – and ideally those driving on these sections of motorway will not even notice. This is because the systems are always very well prepared for the field tests – including intensive testing in different environments within laboratories and non-public areas, among others. And the tests are closely monitored, so that specially trained test drivers and research engineers can intervene quickly if the situation so requires.

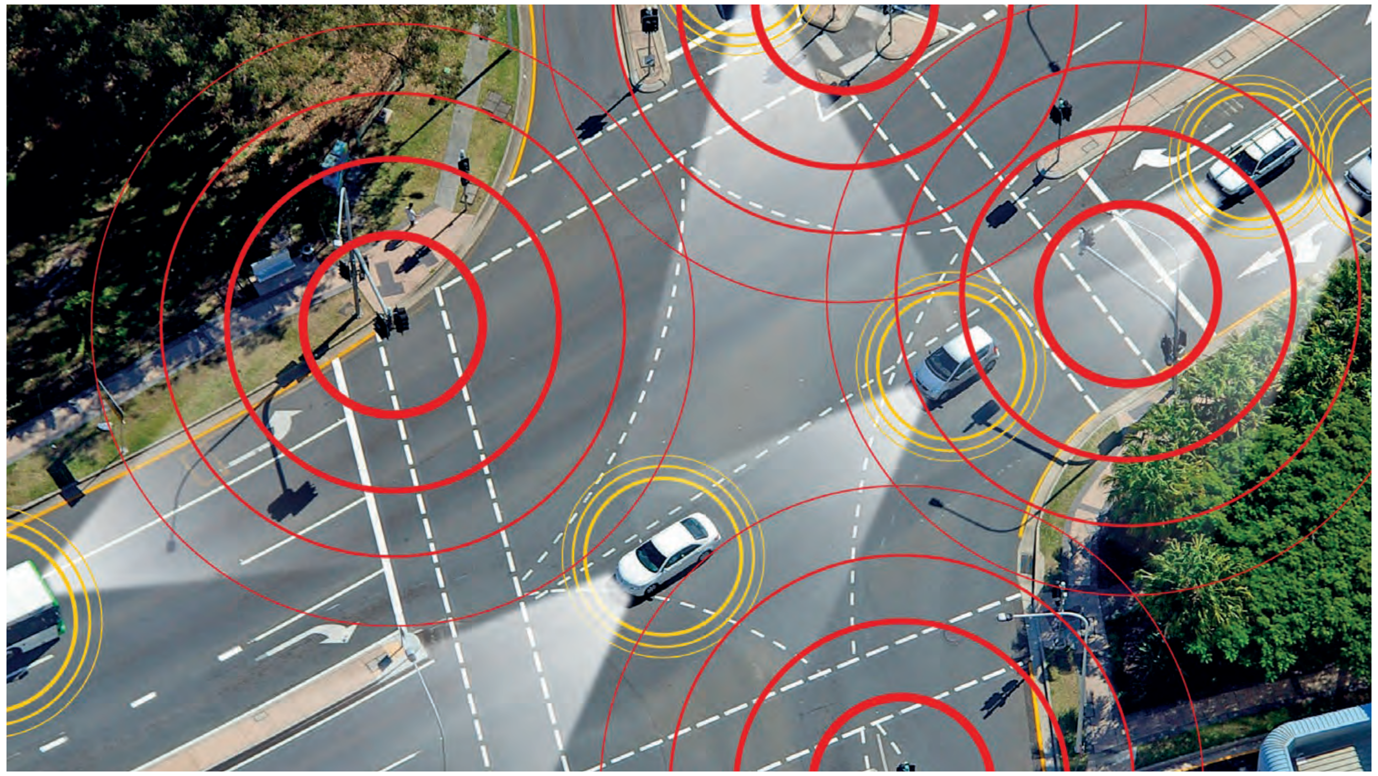
Tools for faster approval

Automated, networked vehicles have been used by commercial companies and scientific institutions, including the DLR Institute of Transportation Systems in Braunschweig, for several years. Practical testing is currently being intensified. However, it has become apparent that the established development methods and approval processes for automated vehicles are no longer adequate. With the test area in Lower Saxony – currently being developed by DLR in close cooperation with the state of Lower Saxony and expected to achieve fully operational status in 2019 – automotive manufacturers and suppliers will have the unique opportunity to drive forward the development of automated and networked road vehicles. With the

PARTNERS ON THE TEST SITE

In constructing the motorway test site, the state of Lower Saxony and DLR have been working closely together, jointly investing five million euro in the gradual development of the test site. Industrial partners that are involved with the test site activities in Lower Saxony include Volkswagen AG, Continental AG, Siemens AG, Wolfsburg AG, IAV GmbH, NORDSYS GmbH, OECON Products & Services GmbH, and ADAC Niedersachsen/Sachsen-Anhalt e.V.





When vehicles are automated, large amounts of data have to be processed. The DLR researchers also consider the back-end support system in the test area.

equipment available at the test site, the users can adapt the new vehicle systems to real requirements and prepare for their respective approval. With its emerging research and development infrastructure, DLR will support national industry, in particular, with the fast, cost-effective market introduction of new products, thus contributing to its competitiveness.

Traffic monitoring and networking

A central component of the test site is the acquisition technology. On a specially selected seven-kilometre stretch of motorway, a series of masts will be erected at 100-metre intervals, each with a camera that records all traffic anonymously and in encrypted form. The data acquired will support the developers in the appropriate design of advanced assistance systems and especially automated, networked vehicle functions. For example, how should an automated vehicle react to plausible non-normative behaviour of conventional vehicles? The data acquired by the camera systems in the test area can, for example, be compared with the data from the vehicles being tested. In this way, the developers can determine whether the vehicles are displaying reasonable behaviour at any given time.

In addition to the sensor technology that an automated vehicle uses to orientate itself, the networking of the vehicles – so-called Car2Car communication – plays an important role in the traffic flow. In order to warn surrounding vehicles about a traffic jam ahead, a connection must be established between two vehicles extremely quickly and reliably. Besides the available wireless mobile technology, also based on ITS G5, such communication is being thoroughly tested on one stretch of the A39 motorway.

A registry is being developed that will accurately record the quality of the lane markings or signage. If a vehicle no longer recognises the lane marking, the developers can check whether it is due to a system fault or whether the marking is no longer properly visible because it has worn off.

From the laboratory to the road

But before the test vehicles can drive autonomously on the test site motorways, they are put through their paces under realistic conditions in virtual traffic environments. To do so, the simulators are equipped with highly accurate maps of the respective stretches of the test site. The ability to run tests beforehand in a realistic simulator simplifies and considerably speeds up the development of the systems. Another important system component of the test site is an extensive back-end support system. This powerful big data system can process huge quantities of data and provide central information.

In designing the Lower Saxony test site, DLR is able to use the experience gained with the Application Platform for Intelligent Mobility (AIM) – which has been fully operative since 2014 – in Braunschweig. The globally unique facility includes a research intersection extensively fitted with cameras and other sensors; powerful back-end support systems; and multiple automated, networked road vehicles.

Frank Köster is head of the industry department at the DLR Institute of Transportation Systems and is responsible for areas such as the automotive and traffic management sectors.

AUTONOMOUS BUSES: WHAT ARE THE REQUIREMENTS?

How can automated and flexible mobility concepts be integrated in the current local public transport system? Would a driverless bus be socially accepted? Within the RAMONA (Realisation of Automated Mobility Strategies in Local Public Transport) project, DLR transport researchers are addressing precisely this question. For this purpose, a test vehicle at the DLR Institute of Transportation Systems was equipped with automated applications to give passengers the impression of an autonomous vehicle. Researchers at the DLR Institute of Transportation Systems are now analysing how well the passengers accept this kind of mobility strategy and what additional requirements they have if there is no driver, and therefore no primary point of contact on the bus. The findings will be incorporated into analyses for the design of future local public transport vehicles that are currently being completed at the DLR Institute of Transportation Systems.

Funded by the German Federal Ministry of Transport and Digital Infrastructure (BMVI), the project started in July 2017 and is scheduled to run for three years. The vehicle will be used in real-life laboratories in Braunschweig and Berlin from 2019. Partners in the DLR-led project are the Association of German Transport Companies (VDV), the Senate Administration for Environment, Transport and Consumer Protection in Berlin, Berliner Verkehrsgesellschaft (BVG), Technical University of Munich (Chair of Ergonomics) and the Esslingen University of Applied Sciences.

Changing the urban scene

By Stefan Trommer

Imagining a future with self-driving cars brings with it a myriad of questions: Will living outside populated hotspots be more attractive when driverless taxis can take you door to door? How will self-driving cars fit into the urban picture? Will the need for parking spaces decrease? What is the risk of traffic chaos?

With advancements in automation come new transport options that will affect everything from the means of transport and the environment to the overall transport system and the urban design. The DLR Institute of Transport Research is conducting comprehensive analyses, scenarios and simulations to estimate how the transport sector will be reorganised and what consequences can be expected. The research conducted at the Institute is providing important assessments to transport policy bodies, the automotive industry, local communities and public transportation providers in order to optimally implement imminent changes.

"Whenever driving has become more attractive, traffic has increased"

To date, increased efficiency, a potential reduction in carbon dioxide emissions, better safety and improved connections to/from rural areas have been heralded in numerous analyses as positive effects of automated driving. But the circumstances under which these benefits will take effect are still not clear. The results of a DLR study conducted for the State Agency for Electric Mobility and Fuel Cell Technology Baden-Wuerttemberg indicate that the increases in efficiency are, for example, dependent on the proportion of automated vehicles over the entire fleet. Model calculations show that overall traffic will only flow more smoothly when at least 30 percent of vehicles are automated.

On closer consideration, less desirable effects are emerging for which we must prepare. For example, it is quite possible that private transport will continue to increase because user groups who until now have not been in a position to drive – such as young people or the elderly – will be more likely to use motorised transport on a regular basis. In addition, the availability of a car will no longer be linked to ownership in future, as is the case with today's car-sharing options. Analyses of mobility developments show that, whenever driving has become more attractive, traffic has increased. Current car-sharing options such as car2go or DriveNow provide users with the possibility of travelling door to door in a city without the hassle of changing trains or buses. In times of high use, the cost of these trips can become attractive enough to compete with public transport services. The potential of such a trend is already visible in major cities in the United States and other countries where, for example, private transport service providers sometimes carry out up to 10 percent of all trips made in urban areas to the disadvantage of public transport operators and traditional taxi companies. In policy terms, therefore, suitable control mechanisms need to be considered at an early stage, in order to promote public transportation by bus and rail. It is evident that cities must decide how the provision of such autonomous transfers is to be implemented in the future.

"We need to reorganise the transport sector"

Automated and networked driving also offers the potential for rethinking current city and road design. In reality, the need for passenger car parking may decline, meaning that the space could be dedicated to other uses in urban areas. In addition, it may be useful to introduce pick-up and drop-off points. This will no doubt change the urban scene. The investigation of such processes needs to go hand in hand with political governance. In this regard, realistic field tests and experimental sites are of particular importance, for example real-life laboratories for testing new mobility concepts and determining the feasibility of technologies and new forms of transport.

Only in this way can automated driving be most efficiently implemented, and hence the quality of life in both urban and surrounding areas improved.

Stefan Trommer is Team Leader of the Technology Acceptance and Benefit Assessment group at the DLR Institute of Transport Research.

Image: DLR/Frank Eppler

Simon Clark at his workplace – the Helmholtz Institute Ulm for Electrochemical Energy Storage (HIU).

KEEP CALM AND CHARGE ON

Whether it is electric vehicles, energy storage systems or mobile phones, progress in the fields of electromobility and energy supply is not possible without safe, high-performance batteries. And on the path to achieve this is an engineer without borders in Ulm.

Simon Clark conducts research on the batteries of tomorrow at DLR and, as an 'engineer without borders', is helping to make the world a better place.

By Denise Nüssle

Four thousand seven hundred and seventy six miles separate the city of Columbus in the US state of Georgia and the university town of Ulm on the edge of the Swabian Alb. For Simon Clark, the journey to distant Germany began during a semester abroad some 10 years ago. It was his first time travelling outside the United States – suitcase packed, passport in hand, ready to try out the first bits and pieces of German he had learned in a language course at his home university. Located in Atlanta, Georgia Tech is one of the leading research universities in the United States. Germany is a popular destination for many of its students, who are drawn here due to the reputation and tradition of its engineers.

Clark arrived in the land of not just engineers, but also the land of the Energiewende (Energy Transition), of regional dialects that often take a little getting used to, and of the dedicated practice known as trash separation. A PhD student, he works at DLR in Ulm, where he conducts research into next-generation batteries to increase the performance and lifetime of mobile devices, as well as to store surplus energy from wind and solar power plants. Clark lives in a small house with a garden in which he enjoys pottering about and making home improvements – a way of life known only too well to Swabians. Thanks to his neighbours, who quickly took this newcomer from the southern United States straight into their hearts, the Swabian vocabulary now comes as easily to him as explaining the local recycling ritual to visitors from his homeland.

What comes after the lithium-ion battery?

At DLR, Clark has the opportunity to collaborate on a truly future-oriented topic that will have a decisive influence on further developments in the fields of mobility and energy supply. From electric vehicles and energy storage systems to laptops and smartphones, lithium-ion batteries are essential in modern technology. There are, however, significant disadvantages to using these batteries. Since lithium is highly flammable, faulty batteries can catch fire or even explode. Their performance and service life are also not keeping pace with increasing user requirements. Furthermore, although lithium is commonly available on Earth, its supply is not unlimited. Future batteries will need to be reusable, which will be expensive. "In order to achieve sustainability with regard to batteries, we are addressing the question of what comes

HELMHOLTZ INSTITUTE ULM (HIU) FOR ELECTROCHEMICAL ENERGY STORAGE

At the HIU, more than 100 scientists research and develop concepts for next generation batteries and beyond as the key to the energy transition and enhanced electromobility. In this way, the HIU is making an important contribution to safeguarding the future in this important field of energy supply. It is also significantly assisting the development of expertise within Germany that establish the country as an attractive research and industry hub. The Institute was founded in 2011 by the Karlsruhe Institute of Technology (KIT) in collaboration with the University of Ulm. Associated partners are DLR – which, like the KIT, is also a member of the Helmholtz Association – and the Centre for Solar Energy and Hydrogen Research (ZSW) in Baden-Württemberg.

Image: Ingenieure ohne Grenzen

Providing technical knowledge for everyday life is one of the principles of the work conducted by Engineers Without Borders

after the lithium battery together with partners from industry and research," says Arnulf Latz. At the DLR Institute of Engineering Thermodynamics, he heads the Computational Electrochemistry department, located at the Helmholtz Institute for Electrochemical Energy Storage in Ulm.

It was through Latz that Clark found his way to DLR. Once he had completed his bachelor's degree, he found his first job in Germany with a small engineering company in Ulm, where he made contact with DLR. The Swabian university town is strongly represented in the area of energy research: in addition to the Helmholtz Institute, other institutions in this field include the local university and the Centre for Solar Energy and Hydrogen Research (ZSW). "The issue of energy is a major challenge for research and society. It is an incredibly interesting field, and an important part of our everyday lives," says Clark, explaining his decision to undertake his master's degree in Energy Science and Technology in Ulm. It was during this time that he became acquainted with Latz, who taught him about simulation and modelling.

More compact and efficient energy storage

In Latz's team, the US-American researcher investigates new battery concepts together with a dozen colleagues. A particular focus is metal air batteries, which have an 'air electrode' (cathode) and a 'metal electrode' (anode). The advantage of this design is that much more energy can be stored in a significantly smaller volume at lower cost. In addition to lithium, other elements being considered are magnesium, sodium, aluminium, calcium, iron and zinc. Clark is focusing on zinc for his doctoral thesis, as part of the EU Horizon 2020 research project ZAS. Zinc is a reactive metal found abundantly in nature, but – in contrast to highly reactive lithium – it can also be safely handled in a humid oxygen atmosphere.

Zinc-air batteries already exist and are used in hearing aids, for example. However, this involves so-called primary batteries, which are not rechargeable. Clark is therefore working on secondary zinc-air batteries, which can be recharged as often as desired and with as little loss of energy as possible. This requires them to exhibit a high cycling stability as well as a long shelf life.

But as ever, the devil is in the details: "This design uses ambient air, so the amount of carbon dioxide it contains can negatively influence the electrochemical processes at play inside the battery cell. This results in a decrease in the performance of the cell – it degrades, as we say," Clark explains. He is therefore investigating the architecture – that is, the optimal composition of such batteries – as well as electrolytes that are particularly suited to them. The electrolyte is a central component in every battery regulating the internal chemical processes. Its mobile, electrically charged ions enable the electrochemical processes that generate the actual power during discharging and then reabsorb it when charging. Electrolytes can be both liquid and solid. "The most difficult task is understanding which complex reaction processes take place in the electrolyte under which conditions, and how these affect the performance of the cell," the DLR scientist says.

Ten more years are likely to pass before the theoretical principles have been developed, the corresponding battery concepts tested and the technology reaches commercial viability. Energy storage systems are considered a promising area of application for zinc-air batteries to store energy from regenerative energy sources and feed it back into the grid as required. In contrast to lithium-ion or lead-acid batteries, they are very safe and non-toxic. "If they suffer damage, they do not explode – they are simply damaged," explains Latz, Clark's supervisor. "Furthermore, due to their higher energy density, zinc-air batteries have the potential to become more cost-effective, compact and powerful than lithium batteries."

Image: Ingenieure ohne Grenzen

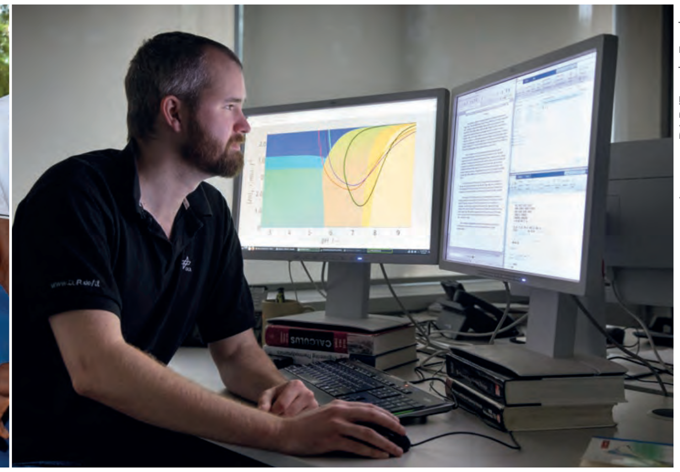


Image: DLR/Frank Eppler

Simon Clark puts heart and soul into what he does – whether it is conveying technology knowledge in Mozambique or his doctoral thesis in Ulm.

The battery of tomorrow – simulated today

Until then, the daily working life of Clark and his colleagues will involve many more hours at the computer. They are developing models and simulating the processes at play in the battery cells. Using this knowledge, the first small battery cells are being built and then tested, for example in laboratory experiments by Stuttgart-based colleagues from the Electrochemical Energy Technology department. Their results are then incorporated into the models. "Charging and discharging a cell 100 times and observing the processes at play often takes months in the laboratory. On the computer we can simulate this in just one day, thus enabling much more targeted and efficient laboratory experiments," explains Clark.

The researcher values both the opportunity to exchange information with his DLR colleagues working on the experiments in Stuttgart and the cooperation with international partners from science and industry. "Together, we keep stumbling upon new factors that we simply could not have foreseen and that we want to investigate further. That is also exactly what I really enjoy about my work at DLR. We are able to conduct research with a long-term perspective and have the freedom to sometimes just try things out. At the same time, our work has high practical applicability – for me, this is the ideal combination."

Engineer without borders

Clark is also energised and on the move around the globe in his free time. Ever since he attended a lecture by the global aid organisation Engineers Without Borders in the US back in 2006, the idea behind it stuck with him. "Our aim is to develop technology on site with the locals in developing countries and to impart knowledge so that it can be used and maintained independently there," says Clark, describing the approach of the organisation. "Merely bringing technical equipment with us and setting it up often does not achieve anything over the long term, as it can become defective and cannot be repaired using local resources." The DLR researcher enjoys the practical work undertaken on site, close to the people and their needs. Since he arrived in Ulm, he has been a committed member of the local Engineers Without Borders group and has helped initiate projects in Honduras and Cameroon.

His first mission took him to Mozambique in 2012 to provide remote schools with electricity. The infrastructure in this south-east African country, torn by civil war until the 1990s, is still poor, particularly in rural areas. More than half of today's adults were never taught to read or write. "Their only option is to catch up on this in the evenings in schools. But this requires light," says Clark, explaining the project's background. So the group led by the DLR scientist developed a lamp that locals can make themselves using simple tools and that is powered by solar panels. "This is learning by doing. The engineers we are training identify much more with their own product and take responsibility for it."

Clark has been to Mozambique on another three occasions. It always takes a little time to mentally adjust to being in a country in which there are no fixed schedules, life is slower, and the countryside has no electricity and roads that are barely paved. "But we have never encountered any problems; most people are very curious, open-minded and friendly. This makes it easy to establish personal relationships, which are extremely important to the success of our project," says Clark, summarising his experiences. He is relaxed about the fact that a lot of his holiday is spent on this commitment: "I gain very diverse perspectives, discover a great deal new things and can focus on something completely different. This gives me fresh impetus and the feeling that I have spent my free time doing something good and meaningful." On the very next day after returning from his last visit in February this year, Clark was back at his office at DLR – after all, he has one year to complete his doctoral thesis.

LOOKING INTO THE FUTURE

The next generation of batteries – projected five year timeline:

Lithium batteries will become better, safer and more cost-effective with lower material usage. Approaches in this direction include, for example, the use of glass as an electrolyte to prevent short circuits and fires, or further developments such as lithium-metal, lithium-sulphur or lithium-air batteries.

The 'generation after next' batteries – projected 10 year plus timeline:

New battery concepts that are independent of lithium. Battery researchers agree on the need to find alternatives to lithium technology, although it is still unclear where exactly the road will take us. Therefore, different approaches – application-dependent – are being pursued.

LIGHTWEIGHT FOR THE SHORT HAUL

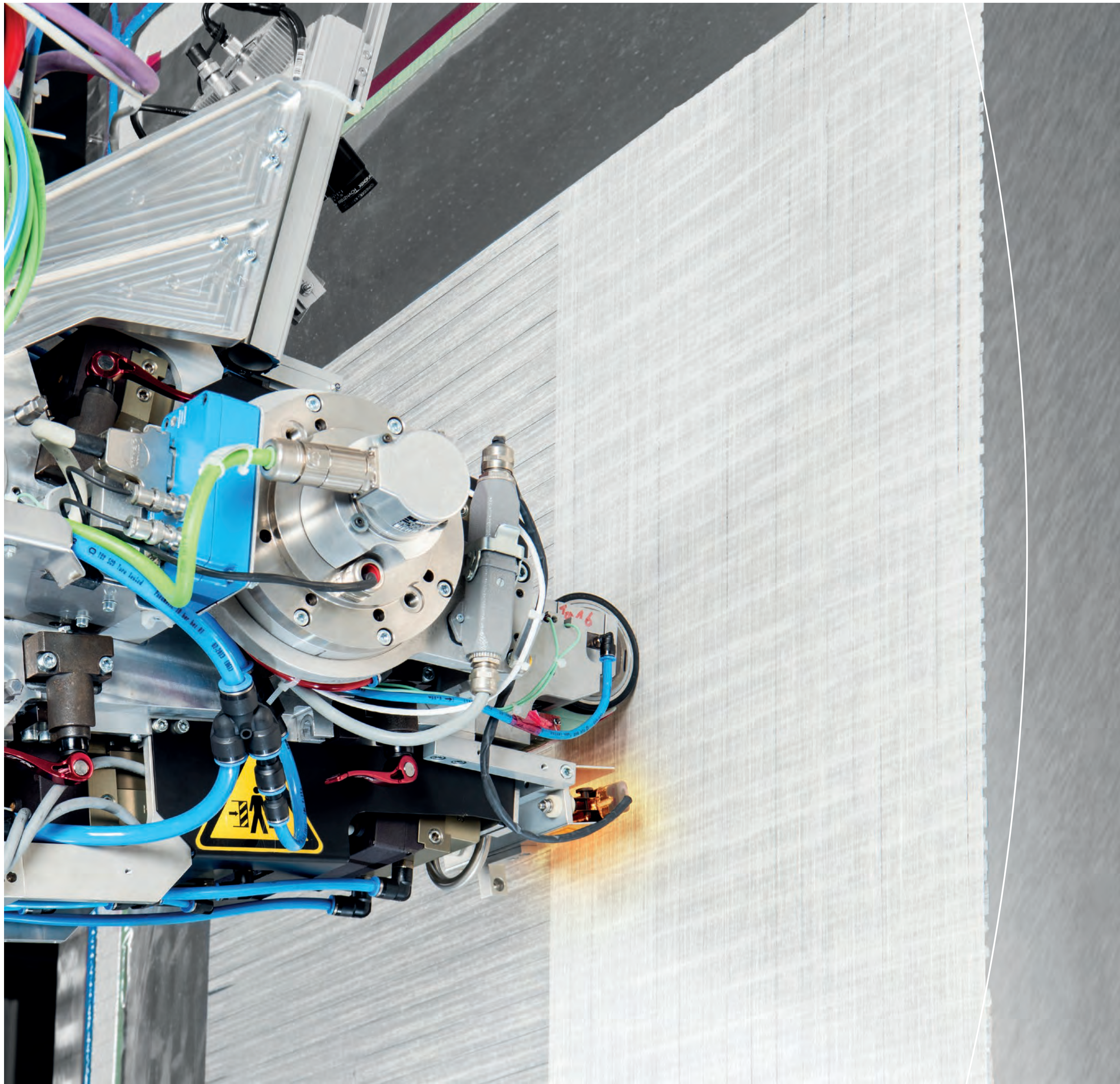
What will the short-range aircraft of tomorrow be like and what characteristics should it have in order to strike a balance between cost and efficiency? These are the questions that DLR researchers aim to answer in cooperation with leading aircraft manufacturer Airbus and its suppliers Premium Aerotec, Fokker and Stelia Aerospace, as well as the Fraunhofer-Gesellschaft. With innovative materials and automated production, DLR is preparing one of Europe's major industries for the future.

Automated component manufacturing using fibre-metal laminates for high production rates in aircraft manufacturing

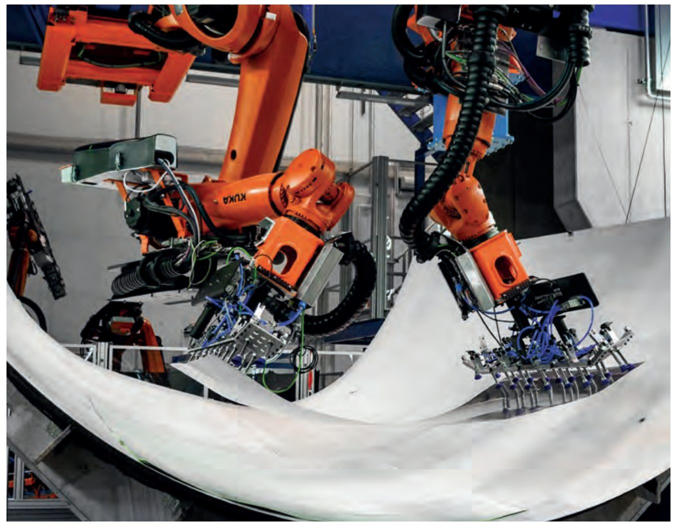
By Jana Hoidis and Nicole Waibel

The term fibre-metal laminates (FMLs) – in particular glass-fibre-aluminium laminate – is one worth remembering for the potential it represents for aircraft manufacturers. Using this high-performance material to manufacture large fuselage components has the potential to make short-haul aircraft up to 400 kilograms lighter while maintaining the same manufacturing costs. "Glass-fibre-aluminium laminate is one of the most promising materials for advanced metal fuselage manufacturing and is therefore a possible solution for next generation aircraft," says Hakan Uçan, the overall project manager. He is optimistic about the future. "The material is lighter than aluminium and, in the case of automated production, is more cost-effective than carbon-fibre-reinforced plastic (CFRP), which is used in the Airbus A350, and is of advantage to aircraft used on long flights. Short-range aircraft often spend more time on the ground than in the air. Fibre-metal laminates would be an efficient alternative in this case."

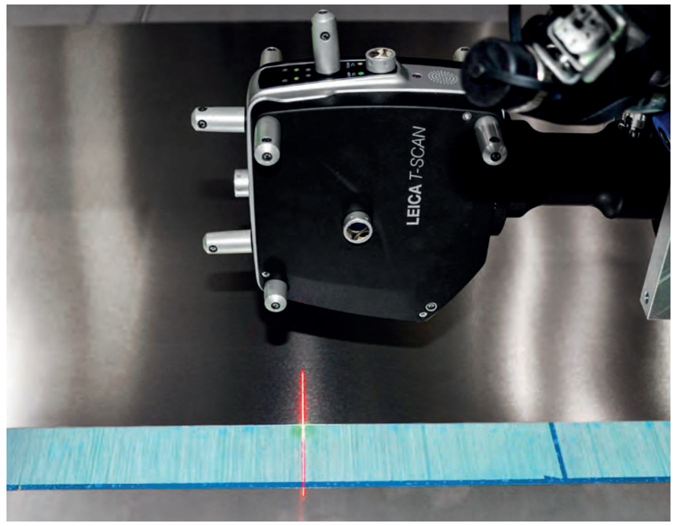
Fibre-metal laminates are a seemingly perfect material for aircraft manufacturing – as long as production is not carried out entirely manually, as is generally the case for fibre composites. For production to be economical, components must be manufactured in a highly automated way. This is exactly what DLR engineers are focusing on. The Institute of Composite Structures and Adaptive Systems in Braunschweig, the Institute of Structures and Design in Stuttgart, the Institute of



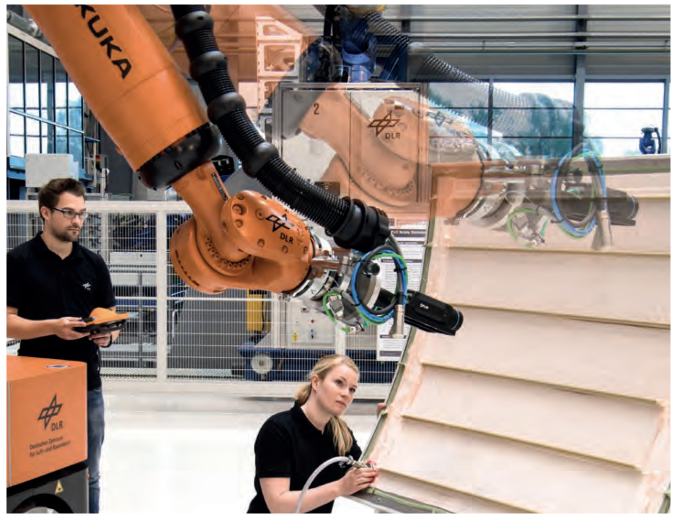
A robot places thin glass-fibre strips. The fibre-metal laminate is built up layer by layer.



Two robots cooperate to place the aluminium



A laser sensor checks the exact placement of the pre-cut aluminium parts



After sealing the component with an airtight film, an infrared camera checks for leaks.

Sensors such as those in the picture ensure the quality of the component while it cures in the autoclave

Materials Research in Cologne and the Center for Lightweight-Production-Technology (ZLP), with its locations in Stade and Augsburg, are working together to convert the production of components made of fibre-metal laminate into automated processes – and facilitate the industrial application of new technologies.

"The advanced technology available in our research and testing facilities enables us to test things that would not be possible for industry alone. Together with our partners, we want to develop an efficient, automated production process for large fuselage segments, enabling both a high degree of quality assurance and high cycling rates," explains Uçan. Around 60 to 70 airplanes are expected to roll off the production line each month from 2025. "An aircraft fuselage comprising large shell components – and therefore a smaller number of individual parts – has fewer riveted longitudinal and transverse seams. This not only saves production steps during assembly, but also makes the aircraft lighter," states Uçan.

Multiple steps – a single process

The production process of a fuselage shell made of FML consists of many individual steps. One of these is the building up of the layers; the individual layers made of aluminium sheet, glass fibre and adhesive film are assembled manually according to the current state of the art. This process is time consuming and prone to error. "Our task at DLR is to transform all the individual steps involved in FML production into an automated process," explains Dorothea Nieberl from ZLP Augsburg, who is coordinating two work packages for the project. First, the different steps are individually examined in detail. Scientists at ZLP in Augsburg are focusing on the application of the aluminium while colleagues at ZLP in Stade are working on glass-fibre placement and the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) is concentrating on the placing of the adhesive film.

"A continuous production chain is essential to ensuring high process reliability and consistent product quality," Nieberl says. Automated quality assurance is also critical to making FML production economic. In today's manual production process, component testing is carried out after production. A quality-assurance concept integrated into the production process itself helps to reduce the number of rejected components and rework. "We are investigating at which points in the production process integrated testing is necessary, possible and ultimately economically viable," Nieberl explains.

Layer upon layer – alternating aluminium and glass fibre

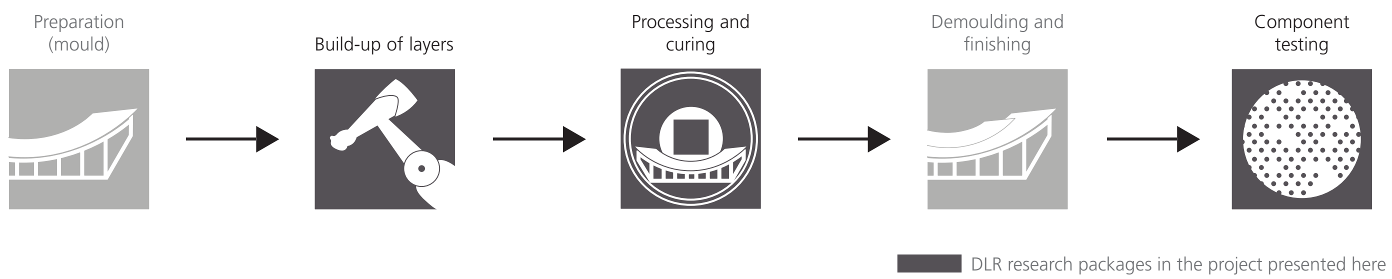
Nieberl states the importance of placing the aluminium foils: "Positioning the sheets accurately, without air inclusions and affecting lower layers is crucial." Due to the aluminium sheets' length of up to eight metres it takes two cooperating robots to achieve this. They each take one of the two ends of the sheet, transport it and place it into the mould. "This enables us to handle even large pre-cut parts safely and bring them into position with high precision," says Nieberl. The robots can pick up the pre-cut parts from various positions – flat or already curved – and place them in the mould for the fuselage shell. "We are further developing a strip gripper for the aluminium placement that we had previously designed for the manufacture of CFRPs."

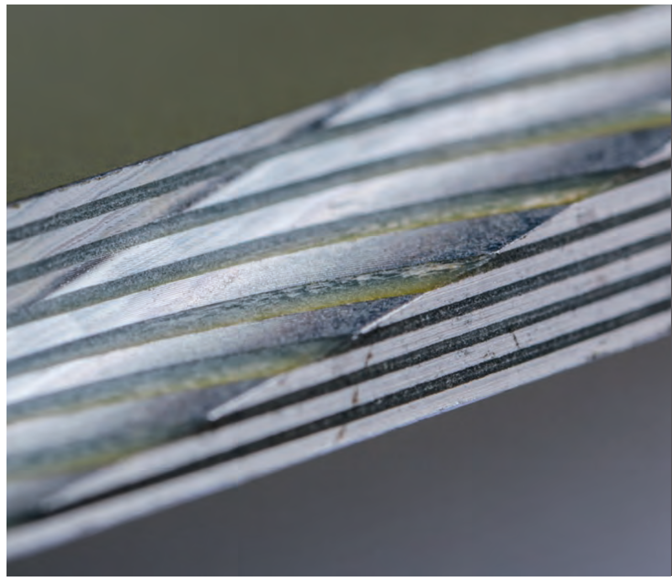
Another concept from CFRP manufacturing is being adapted for the application of glass fibres. Automated fibre-placement technology (AFP) is a robot-based process that is used to place multiple glass fibres – pre-impregnated with resin – into a mould. The advantages of this technology lie in the precise and automated placement of the fibres. The trimming previously required is no longer necessary, thus reducing the typical amount of material wastage.

In addition to path planning, simulation and programming of the robots, reliable quality assurance is also among the researchers' tasks. The positioning accuracy of the placement of the aluminium sheets is guaranteed by means of a laser-based procedure to ensure that they are placed into the mould without any gaps or folds. In the case of glass fibre placement, a laser sensor also checks for undesirable spaces between the individual fibre tracts and searches for faults in the material.

Uçan explains why DLR is particularly suited to this research: "Since 2009, our scientists at the Stade and Augsburg sites have been developing research facilities with which large-scale structural components can be manufactured in an automated way. These facilities are ideal for constructing parts on a 1:1 scale. In this way, we can offer our industry partners a flexible opportunity to develop a technology with a high degree of maturity so that it can be transferred to industrial production without much additional development expenditure."

Overall process chain for component manufacturing using fibre-metal laminate (FML)





What are fibre-metal laminates?

A fibre-metal laminate (FML) consists of multiple layers of metal sheet, 0.2 to 0.5 millimetres in thickness, alternately bonded with fibre reinforced plastic. These laminates are high-performance materials used in modern aircraft manufacturing and combine the benefits of metals with those of fibre-reinforced plastics. The first usage of FMLs on a large scale was in the form of glass fibre reinforced plastic (GFRP) combined with aluminium on the Airbus A380. The GFRP layers reduce the spread of possible cracks and the fatigue behaviour offers advantages over pure aluminium. In addition, glass-fibre aluminium laminate is lighter than traditional aluminium and the base materials are more cost-effective than those for carbon fibre reinforced plastic (CFRP).

JEC World in Paris with start-up competition

In the coming year, DLR will once again be attending JEC World, the world's largest trade fair for the fibre composite industry – to be held in Paris from 6 to 8 March 2018 – and will present its latest developments in this sector. Paris is at the same time the mainstay of the largest international start-up competition for innovations in the fibre composite industry.

Further information, including how to submit projects, can be found at **bit.ly/2uPCWLS**

Stiffening and curing

Once the 'skin' has been created on the tool, the stiffeners – referred to as stringers – must be applied. "We bond the stringers using a patented technology that has been specially developed for this purpose. Using electromagnetic induction, heat is directly generated at the bonding site within a very short space of time, similar to how an induction cooker works. This shortens the process time from around one minute to just a few seconds," says Uçan, explaining the advantages of induction compared with conventional heating methods. The stringers and fuselage skin are sealed together with a vacuum foil. Even the smallest of leaks, such as holes in the foil, can negatively influence the quality of the component. A specially developed leakage detection system that uses infrared technology identifies leaks in the foil before the component is placed in the BALU™ autoclave, where it is finally cured. In order to monitor the component's interior accurately, the researchers use fibre-optic sensors located next to the other glass fibres in the component. Further curing sensors that monitor the component from the outside are also being investigated. This will enable information about the internal condition of the material to be called up throughout the entire process time.

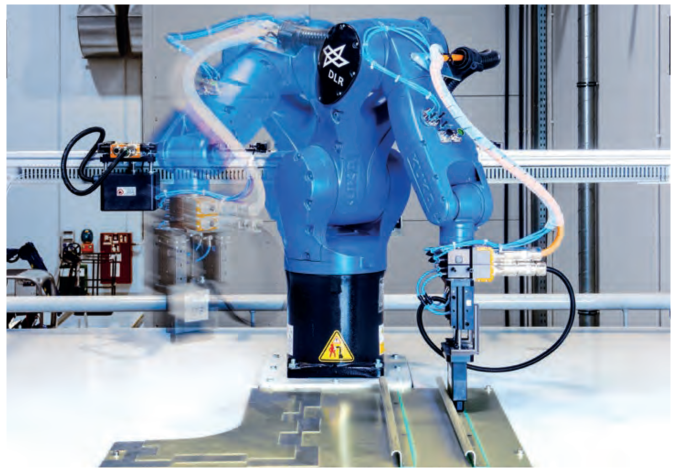
"A fibre-metal laminate comprised of glass-fibre-reinforced plastic and aluminium develops complicated residual stress behaviour during production," explains Erik Kappel from the Braunschweig institute. "Already during the autoclave process, we can use the sensors to detect whether a part will deform after curing and immediately change process parameters such as temperature and pressure." This can be thought of similarly to baking a cake. If baked for too short a time, too long or at the incorrect temperature, the cake may collapse after baking or be burnt. "The sensors are like using a wooden skewer to check whether the cake mixture has been thoroughly baked," Uçan adds in simple terms. "We can use them to monitor a large number of properties." They all have one aim – to derive optimised autoclave processes, so that a component will always be manufactured successfully on the first attempt, thus ensuring consistent product quality.

Lethal test for the material

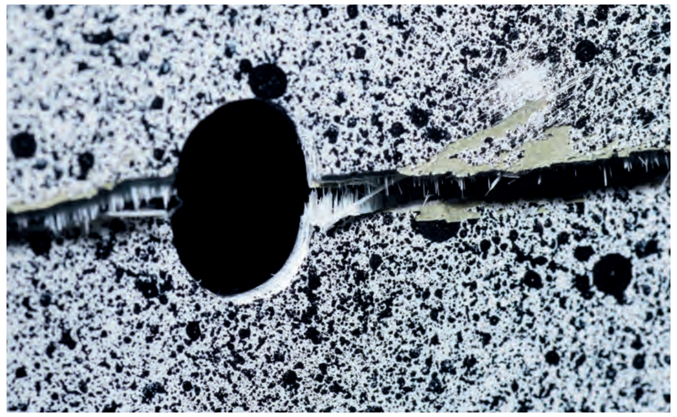
At the Institute of Materials Research in Cologne, Guillermo Requena, Julian Schwinn and a team of scientists are testing how the fibre metal laminates react after inserting holes. Aircraft manufacturing requires thousands of holes. Every rivet used to join components means a small hole must be made – and every hole weakens the material. This must be taken into account when designing the structure. "The more we learn about the true extent of this weakening, the less additional material we need to use to compensate for it," Requena emphasises.

Blunt-notch tests determine the tensile strength of fibre-metal laminates with rivet holes. Material samples are clamped into a biaxial testing machine used to pull the material apart or push it together in two directions at the same time. "With the biaxial testing machine at the Institute, we can investigate individual effects in a targeted way, including fracture-mechanical behaviour such as cracks, or the behaviour of whole structures. Aircraft skin with stringers can also be examined in this way," Requena explains. "Our aim is to create a model that enables us to predict behaviour with the holes. In this way, we can explore the fields of application for FML and make full use of the material's properties."

Jana Hoidis is responsible for public relations at the Institute of Composite Structures and Adaptive Systems.
Nicole Waibel carries out the same function at the Institute of Structures and Design.



Researchers at the Center for Lightweight-Production- Technology (ZLP) in Stade are studying how the inductive pre-bonding of stiffening elements can be automated



A cruciform test specimen clamped in the biaxial test machine at the Institute of Materials Research in Cologne (lower left), and a close-up of a torn fibre-metal laminate sample.

Hakan Uçan ...
studied mechanical engineering at the Technical University of Darmstadt. He has been working at the Institute of Composite Structures and Adaptive Systems in Stade since 2009. As team leader, he is responsible for the field of curing and infusion processes for lightweight structures. Uçan is the overall manager of the project presented here and coordinates the work at the DLR Augsburg, Braunschweig, Cologne and Stade sites.

Looking to the future

Three questions for Project Leader **Hakan Uçan**

What are your next research objectives?
: In the near term, until 2021, we are focusing on developing a new process chain for the manufacture of fuselage shells. In addition to automating the production of fibre-metal laminates for the first time, we want to produce large aircraft shells. Together with our industry partners, we have already enjoyed partial success with the first automated placement process for a fuselage shell section. This represents an important step on the way towards industrialisation of this technology right up to series production. DLR is contributing key technologies for this.

Where do you see fibre-metal laminates in 15 years' time?
: For years now, the number of airline passengers on short-haul routes, and therefore the number of aircraft, has been on the rise. It is likely that this trend will continue. A few years ago, short flights such as from Frankfurt to Munich were not even discussed – but today, they are part of everyday life. There has been talk of a next short-range airplane for some time now. This will happen, but when this will be and what material it will be made of depends on many factors. If we succeed in ensuring that FML can be produced efficiently and in an automated way, it will have a good chance of being installed in future aircraft.

Is this new material also relevant to other fields?
: The material is currently being considered for future generations of aircraft. Theoretically, due to its low weight and – compared with aluminium – its better mechanical properties, it could also be relevant to the automotive industry. However, everything begins and ends with the cost; more research needs to be conducted to achieve economical production in large quantities in order to reduce the costs accordingly. Over the long term, FML could also establish itself in our daily lives, as has been the case for many other high-performance materials, such as CFRP. We will just have to wait and see which everyday objects are made of fibre-metal laminates in a few years' time …

MAIDEN FLIGHT OF THE 'MANTA RAY'

Collaborative aircraft design makes premiere in simulator possible

By Falk Dambowsky

As the pilot makes a left-hand turn, passengers on the far-right side of the aircraft are gently pushed back into their seats, and passengers on the far left feel a little bit lighter for a moment. He knows that he must ensure the comfort of 450 passengers during such manoeuvres. The pilot in question sits at the controls of a Blended Wing Body – known as a BWB – a manta ray-shaped aircraft configuration in which the fuselage is flattened to generate additional lift.

The flight deck that provides this spectacular insight into the future of global intercontinental transport is a simulator at DLR in Braunschweig. At the controls of the BWB – which at the moment only exists virtually – sits Yasim Julian Hasan from the DLR Institute of Flight Systems. He has been testing the flight characteristics of the unusual aircraft. "Despite its wide body and the resulting large mass moment of inertia, the BWB is very agile to fly in a rolling motion, rotating around the aircraft's longitudinal axis," he says, flying along another prolonged curve. "However, one difficulty is a strong rudder input," Hasan adds. "This leads to an unfavourable sideslip angle that excites the insufficiently damped Dutch Roll mode – a combination of yawing and rolling oscillations." Looking out of the cockpit window gives the impression that the distant landscape is slowly rolling backwards and forwards in a gentle circular motion. Hasan damps the oscillations with a combined deflection of the aileron and rudder and continues his calm course. "In future, the BWB will need a special control system that will stabilise occurrences such as a Dutch Roll," Hasan explains, demonstrating another special feature of the majestic ray-shaped jumbo jet. Using the three engines mounted on top of the rear end of the fuselage, he accelerates. As he does so, the nose slowly begins to dip downwards. "Due the uncommon position of the engines on top of the fuselage, the increase in thrust generates a pitching moment that has to be compensated for by pulling the elevator," Hasan says. "These properties of the BWB in terms of controllability have already been theoretically computed using digital tools, but an astonishing level of detail in the flight characteristics can now be established in the simulator."

This is the first time a blended wing body has been flown virtually in the Air Vehicle Simulator (AVES) in Braunschweig. This maiden 'flight' is the result of the DLR FrEACs (Future Enhanced Aircraft Configurations) project, which has been working on the integrated design of a medium-sized BWB for long-haul flight since 2014. "In total, 11 DLR institutes have contributed their expertise to the design and evaluation of the BWB," says project leader Till Pfeiffer from the DLR Institute of Air Transportation Systems in Hamburg. "The maiden flight in the simulator is the culmination of our work to date."

But at the outset it was unclear what shape the BWB would take under ideal conditions. "Very different designs were discussed between the various disciplines," Pfeiffer says. "These included versions with small winglets, with one or two engines under the wings, or a traditional vertical stabiliser above the tail." Ultimately, the preferred version proved to be a BWB with three engines mounted next to one another above the tail section and framed by two stabilisers. Flaps on the rear of the midsection act as elevators. "This shape makes the BWB very fuel-efficient to fly and the positioning of the engines above the fuselage also makes for particularly quiet flights."

As many as 20 DLR researchers met in design workshops, from the aircraft design manager – who developed the overall concept and the fuselage shape – to the aerodynamicist, the engine technician and the flight mechanic who ultimately analyses the flight behaviour of the completed model. "Normally, each discipline works independently and passes its interpretative results on to the next discipline," Pfeiffer explains. "We, on the other hand, cooperated closely to develop a shared process chain, in which all disciplines work with the same data set."

In order to do this, a special data format called CPACS (Common Parametric Aircraft Configuration Scheme) was developed at DLR. This enables immediate representation of how structural changes in one discipline affect the others. "If, for example, the aerodynamicist wants to make a wing narrower, our system can immediately show whether a smaller engine can be used under certain circumstances as a result, and whether these changes affect the structure or the flight control systems being integrated," Pfeiffer says. "Thanks to our interdisciplinary collaboration, we have become much more flexible in aircraft design."

The researchers have now been able to extend this newly achieved flexibility to the maiden flight of new models in the simulator. "In traditional aircraft design, simulator tests would only be carried out by research and industry once the new model had been optimised as far as possible by every discipline," Pfeiffer explains. "With our interface between the model and the simulator – as demonstrated in the maiden flight of the BWB – new aircraft configurations can be flown virtually by pilots and evaluated at a very early stage."

It will be exciting to see which futuristic designs will soon take off virtually in Braunschweig.

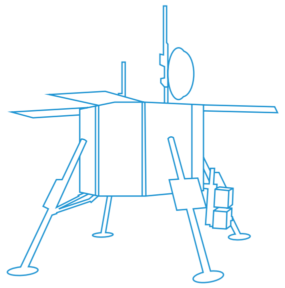
www.cpacs.de

THE FREACS PROJECT

The DLR FrEACs (Future Enhanced Aircraft Configurations) project aims to quantify uncertainties in the design process and consider these in the design of two unconventional aircraft configurations. A Blended Wing Body (BWB) is being considered for long-haul flights and a planned market launch from 2035, along with an innovative short-haul configuration. At DLR, there are already evaluation processes for aircraft regarding cost, airside capacity and noise. These have been integrated into the design process. The project, which runs for three years (2014 to 2017), has been allocated a budget of around six million euro. Eleven DLR institutes and facilities are involved: the Institute of Aerodynamics and Flow Technology; the Institute of Aeroelasticity; the Institute of Propulsion Technology; the Institute of Structures and Design; the Institute of Composite Structures and Adaptive Systems; the Institute of Flight Guidance; the Institute of Flight Systems; and the Institute of System Dynamics and Control, in addition to the Systemhaus Technik facility, the Simulation and Software Technology facility and the Air Transportation Systems facility (Project lead).

Graphical representation of the development stages

'SOLO' SPACE ODYSSEY



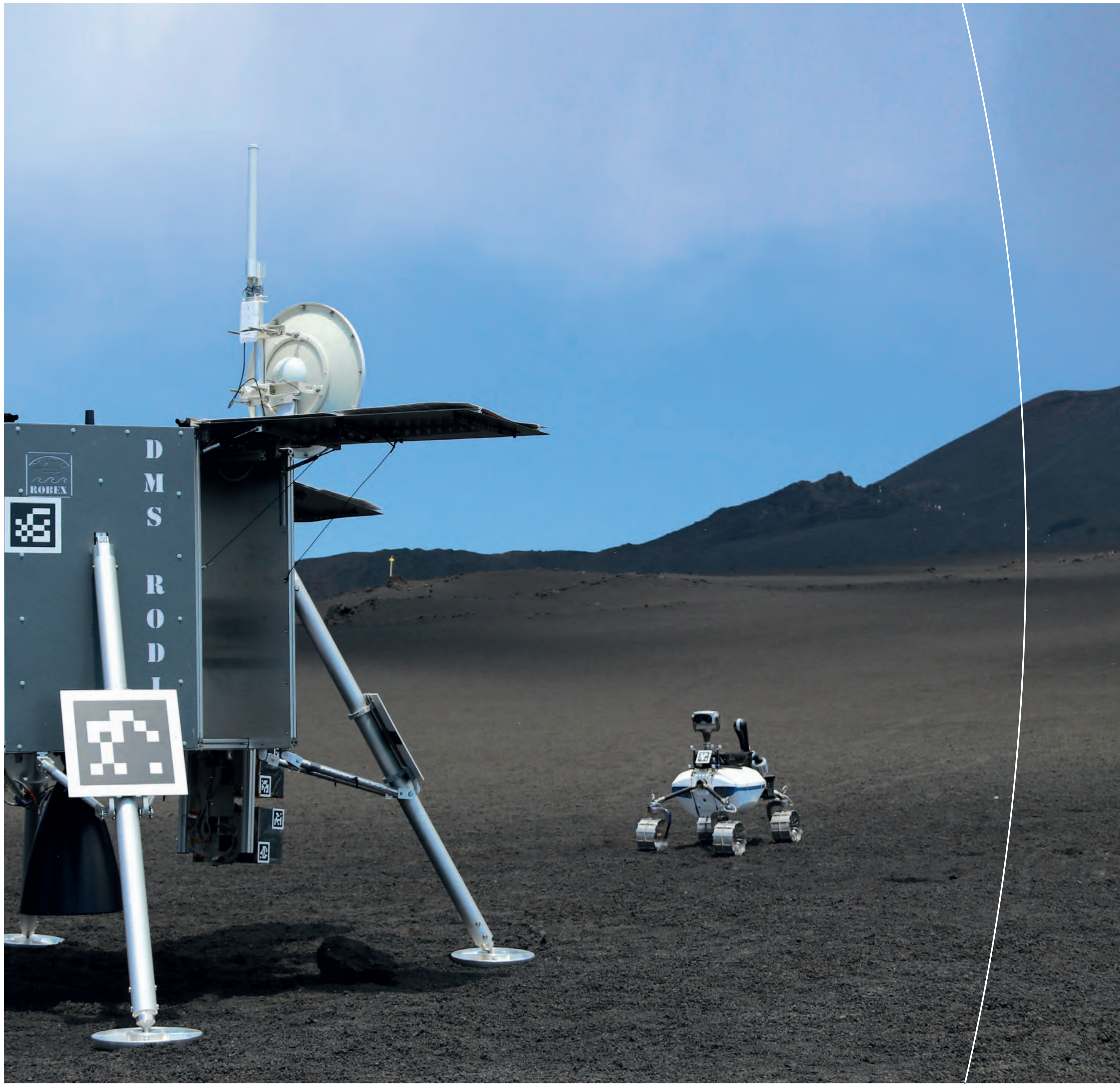
A world first. Never before have deep-sea and space researchers collaborated on a project to exchange knowledge and co-develop technologies. Over the past five years, engineers and researchers from the two disciplines have been working together on the Helmholtz Alliance Robotic Exploration of Extreme Environments (ROBEX). In the final year of the cooperation, space scientists put their technologies to the test during a demonstration mission on Mount Etna – a lunar analogue landscape. The challenges – autonomous navigation, innovative energy exchange and efficient data transfer. The goal of the analogue mission – to set up a network of sensor units to, for the first time, determine the Moon's interior structure and the composition of lunar regolith.

Testing ROBEX technologies for planetary exploration

By Manuela Braun

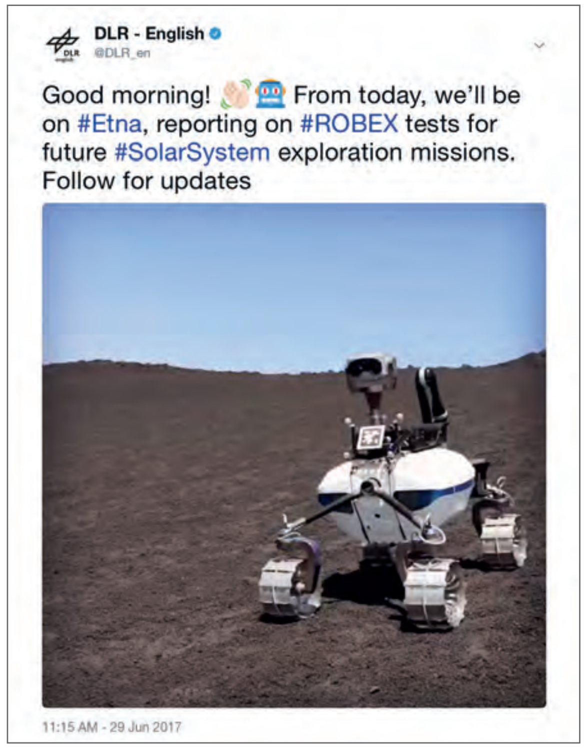
It is an ordinary day in Pedara, Sicily. Four pensioners sit on a park bench – in the morning they enjoy the Sun on the left side of the street, and in the afternoon they move to the sunbathed right side of the street. Peter Kyr waves at them from his car window, just as he has done every day for four weeks during the journey from the coastal town of Catania, through Italian villages scattered along the way up to Mount Etna, the location of the ROBEX mission. In the throng of narrow streets and houses with gently flaking paint, all uphill roads somehow lead to Etna. The road through Pedara with its bench of pensioners is but one. Kyr waves at the pensioners every day, and every day the honourable quartet ignores this friendly greeting. Nevertheless, it has become a ritual on the one-hour trip to the cable car station at an altitude of 2300 metres.

Every morning, shortly before 08:00, some 30 scientists and engineers climb into the small rental buses in front of their hotel. It is already more than 25 degrees Celsius on the coast, and the team, sporting hiking boots and long trousers, feel the heat. Even so, they are all carrying pullovers, jackets and hats. At the end of the four-week mission, a rover is expected to autonomously set up a network of seismic measurement stations to record vibrations in the ground on Etna, where the weather is unpredictable. The volcano can be draped in banks of clouds within moments, reducing visibility to just a few metres. Then, the temperature drops to a few degrees Celsius and powerful gusts of wind sweep across the black lava landscape. Occasionally, the Sun makes an appearance, heating the air to approximately 20 degrees and causing sunburn.



THE ROBEX PROJECT

The Helmholtz Alliance ROBEX (Robotic Exploration of Extreme Environments) brings together the Alfred Wegener Institute for Polar and Marine Research – the coordinating institute – with various other institutions in Germany like GEOMAR and the MARUM as well as the technical universities of Dresden, Kaiserslautern, Munich and Berlin, the Universities of Bremen and Würzburg, Airbus and the German Research Center for Artificial Intelligence (Deutsche Forschungszentrum für Künstliche Intelligenz GmbH; DFKI). DLR's involvement includes the Robotics and Mechatronics Center, the Institute of Planetary Research, the Institute of Space Systems, the Space Operations and Training Facility and the Institute of Composite Structures and Adaptive Systems.



The mission was promoted worldwide through DLR's crossmedia platforms. Forty-one tweets in German and English reached 209,950 users. Four blog posts and various entries on Instagram and Facebook made ROBEX widely known.

Out-of-this-world laboratory

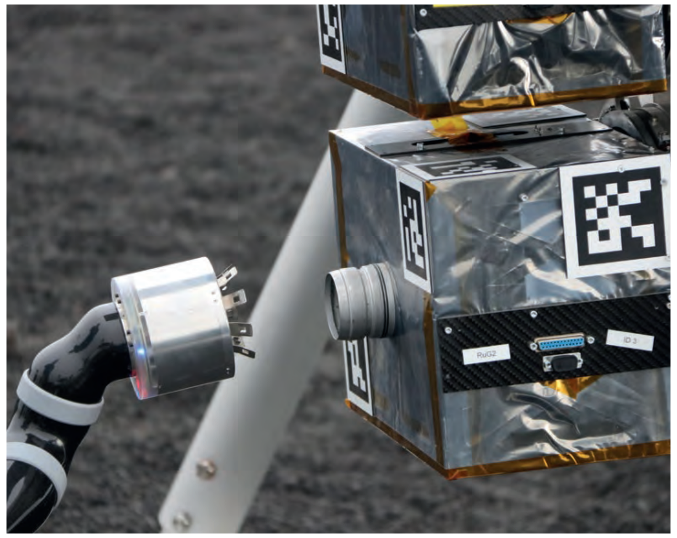
SUVs are necessary to drive up to the 2600-metre-high test site – a 'Moon' on Earth for the duration of the mission. With its barren landscape and sulphurous volcanic cones, Etna is otherworldly. But in the eyes of the LRU-1 (Lightweight Rover Unit) camera, it is a bit like home – after all, it was made to drive and work on the Moon. Engineer Norbert Todt shows the team a photomontage of the RODIN lander, the LRU-1 rover and, instead of a blue sky with clouds, a black sky with a view of Earth. Even a real photograph could hardly look more like a lunar mission.

On the Moon, the lander, rover and instruments will be on their own – their creators and operators unable to intervene on site. For this reason, the vehicles and equipment are designed in such a way that they can independently run through programmed sequences and also make the right 'decisions' for their research assignment. An autonomous car, which finds its own way through traffic while avoiding obstacles, is still a pipe dream on Earth. In space, there is an additional difficulty – practice runs are not possible. What is more, the ambient conditions are extreme, with alternating glaring light and profound darkness, microgravity, space radiation and a great distance to the control centre.

Communication is everything

Pling. Pling. The small pebbles continuously pelting the metal wheels on which the rover slowly but steadily heads towards the lander make quite a sharp noise. Added to this is the dull grinding sound with which the lava, resembling dark cat litter, gives way beneath the rover. "How is the battery doing?" asks Bernd Vodermayer via a walkie-talkie in the control centre located along the coast, in Catania, 23 kilometres away as the crow flies. During a mission to the Moon, no one sits within visual range to control the rover. This is why everything needs to run autonomously – recording the environment with a camera, planning a safe route, recognising the sensor units and picking them up with a robotic arm. Throughout this process, the lander – which acts as a relay station to the control centre and also supplies power – the rover and the sensor units containing the seismic instruments need to communicate with one another and exchange information.

Out of the crackling walkie-talkie comes the news that battery is just about discharged. On the Moon, the rover would need to take lengthy breaks to replenish its energy reserves via solar panels. During the experiment on Etna, waiting for hours is not an option. For this reason, Bernhard Rebele trudges the 80 metres up to the base camp and back to the test site several times a day to fetch charged batteries for LRU-1. Here on Etna, the rover must also cope with gravity. On the Moon, however, its own weight or that of the three-kilogram sensor unit would hardly be noticeable, and the wind that complicates the passage through the lava landscape for the scientists would be non-existent. But there is no place on Earth exactly like the Moon.



It looks simple, but it is not. The rover examines the sensor unit (right), and then moves its gripping device (left) to the connector.

Image: Mauro D'Agati/Agentur Focus

The mission is explained to Chair of the DLR Executive Board, Pascale Ehrenfreund. DLR engineer Lars Witte discusses the technological possibilities of ROBEX for a Moon mission with the renowned astrobiologist.

The base camp, with its containers, is, at the same time, a warehouse, control centre, sunshade and laboratory.

Temperamental rover

So far, all of the units – the lander, rover and instrument box – have passed the tests in their home laboratories. Now they are combined for the first time and must cope with a real lava surface, wind and breakdowns in communication. Signs are attached to the loading bays on the 500-kilogram lander and to the sensor units, for the rover to detect and scan for orientation purposes. It grinds its way towards the RODIN lander and fixes its gaze on the black-and-white pattern. It carries on staring – doing nothing at all. A small group huddles around the rover. Stepping in front of the camera is forbidden – that would confuse it even more. "Is it doing anything?" Vodermeyer asks. Out of the walkie-talkie comes the frustrating answer from the control centre: "No. Abort." LRU-1 can be temperamental at times. If it does not recognise its environment or does not know how to orientate itself, it stops moving. If there is a risk that the load is too heavy for its robot arm, it simply puts it back down.

On previous days, the lander had not played along when it was supposed to take the sensor units out of the loading bays without the intervention of its operators. This caused some disquiet among the team from the DLR Institute of Space Systems that developed and built RODIN. For the DLR planetary researchers, this is often a test of patience. The scientists will only be able to measure what is happening in Etna's interior once the rover has set out the sensitive seismic instruments as planned.

"The interaction between ground control, science and technology has to be rehearsed first," says Armin Wedler. The engineer from the DLR Institute of Robotics and Mechatronics is DLR's project leader for the ROBEX mission, in which five DLR institutes are participating. It also takes time for a collaboration routine to gradually develop among 40 cooperating scientists and engineers on site in Sicily.

Only if the antennas are exactly aligned can the communications between the lander, the rover, the sensor unit and the control centre function correctly.

Planetary scientists simulate meteorite impacts with a hammer. The sequence of impacts is accurately recorded.

Space science on a volcano

In the midst of change, there is one constant – work days on Mount Etna are long. Every morning, the team make their way through Italian traffic from Catania to the cable car station, and then drive the final 300 metres up to the base camp in SUVs. There, the containers into which the crates, rover and sensor units are stowed away every evening are unpacked again, and the base camp comes back to life. Every day, the devices, the rover and the equipment are covered with a fine but sticky layer of lava dust. Shoes and trousers up to the knees are coloured with a slight shade of black. As evening sets in, the SUVs return to the coast. The demonstration mission is coming to an end – and they still have not managed to execute the entire autonomous sequence without problems. Time and again, the individual steps run flawlessly, but unfortunately fail to do so when combined. Software problems and communications issues are addressed as the team makes its 2600-metre descent back down to sea level.

The ROBEX researchers and their rover are an attraction for Etna tourists, and receive just as much attention as the volcano itself. While the planetary researchers wait for their measurement data, they make themselves useful: "What we are doing here is investigating technology that can be used on a mission to the Moon," Alexandra Heffels from the DLR Institute of Planetary Research says to a group of hikers, who came across the space scientists on their way to Etna. With these words, the scientist repeatedly interacts with groups of tourists who – unwittingly – have stumbled across the 'Moon' and interrupted an autonomous exploration mission.

Meteorite impacts with a hammer

Finally, all is running smoothly and the planetary researchers can collect the first data on how sound propagates through the various lava layers. To do this, they need a five-kilogram hammer with which to simulate the impact of meteorites that repeatedly hit the Moon. Back in Berlin, the team practised how to powerfully and precisely strike an aluminium plate with a hammer to produce sound waves that the seismometers in the sensor units can measure. Sabrina Schwinger takes position. When the instruments are taking measurements, everyone must stand still – every vibration will be picked up by the sensitive sensors and could contaminate the data. Only Etna itself ignores this, as it has done several times today already, spewing out a black cloud of ash that rises above the sulphuric cone like a flag.

Frank Sohl grabs a notepad and pencil. Schwinger hammers the aluminium plate 20 times – as precisely and evenly as clockwork. Meanwhile at the control centre in Catania, Martin Knapmeyer observes the impacts being recorded by the seismometers. "They look very good," he reports back to his colleagues on the mountain. Later, the scientists will evaluate and analyse this data at their desks in Berlin, in order to see at what depth the loose lava layer ends and the solid one begins. The sound propagates through solid basalt rock at six to eight kilometres per second, but 'crawls' through volcanic ash at just a few hundred metres per second. Such measurements were carried out on the Moon for the first and last time in 1972 – not autonomously by a rover and sensor units, but by astronauts Eugene Cernan and Harrison Schmitt during the Apollo 17 mission.

Squalls just before completion

Things are not looking up for the ROBEX engineers. Again and again, squalls of over 50 kilometres per hour sweep across the earthly lunar landscape. The gusts stir up clouds of dust and push against the robotic arm that LRU-1 uses to grip the sensor units. Shortly before the mission is due to end, it is no longer possible to do anything: The wind sensor on the lander is showing values of over 100 kilometres per hour. The storm is even blowing the ground underneath the containers to the side. The lander is secured with straps so that the loading bay flaps are not opened and damaged. The rover remains in its 'garage'. The wind that is lacking on the Moon seems to be on Etna today.

What can be battened down is battened down. Then the teams return to the coast, where scorching 30-degree weather has tourists in T-shirts, shorts and flip-flops, drenched in sweat. The team is gradually getting closer and closer to autonomy, but now the weather is no longer cooperating. The team, the rover and the lander are forced to take a break.

At this point, the level of frustration is high. Nobody knows whether the final days will offer an opportunity to execute the mission. In fact, researchers wanted to demonstrate to invited guests how successfully the technologies could be used: the rover with its autonomous navigation; the lander guaranteeing communication; the sensor units with their sensitive instruments; and the rover's inductive charging device. If everyone had known on that evening that it would all be quite different just a few days later, spirits would have been higher. The weather forecast is checked over and over again on mobile phones. The rover and lander can only be reactivated if the wind drops.

Mission accomplished!

Finally, the time has come. The wind eases up a little, and the Sun even provides bearable temperatures on the mountain. The RODIN lander and LRU-1 rover are no longer uncooperative. LRU-1 purposefully approaches the lander, locates it and unerringly backs into a spot in front of the loading bay. Its robotic arm is deployed and moves towards the sensor unit on a self-computed path. Then the gripper device closes around the connecting ring, undocks the unit and the robotic arm accurately sets down its payload on the back of the rover. It grinds its way across the lava soil to place the first sensor unit at the predetermined location. The future has favoured the bold. The ROBEX team leaves Etna, headed back home after a 'Moon odyssey'.

Success of an alliance: Martina Wilde from AWI and DLR's Armin Wedler

TEAMWORK IS KEY

Deep sea meets space – researchers from these two fields have been collaborating within the ROBEX (Robotic Exploration of Extreme Environments) Helmholtz Alliance since 2012. DLR project leader Armin Wedler and science coordinator Martina Wilde from the Alfred Wegener Institute (AWI) speak to DLR space editor/writer Manuela Braun about the project.

How did the collaboration between these research areas come about?
: Martina Wilde: Originally it was 'decreed' – the Helmholtz Alliance combined two separate funding requests, and the result was the HGF ROBEX Alliance with 16 institutions spread across Germany. Today, the alliance is such a successful collaboration that DLR, AWI and the GEOMAR Helmholtz Centre are participating in ROBEX and have teamed up on the new ARCHES funded project.

At first glance, deep sea and space do not have much in common. Where are the synergies in the alliance?
: Armin Wedler: The overlaps are in the challenges that deep sea and space present as extreme environments. These issues include the need for autonomy in exploration devices, navigation difficulties and the complicated energy supply.

What can deep-sea researchers learn from space researchers?
: Martina Wilde: They benefit enormously from the technologies and software developments that are already being used successfully in spaceflight. The software and navigation markers used for docking the Automated Transfer Vehicle (ATV) to the International Space Station (ISS) are now being deployed in deep-sea research and are enabling an unprecedented level of autonomy.

And what have space scientists learned from their colleagues in deep-sea research?
: Armin Wedler: We have acquired technological approaches such as modularity – as well as gained the courage to work in extreme environments and adopt the pragmatic approach that is helpful for such an experiment.

SAFE AT SEA

Shipping is becoming digital. Cutting-edge navigation, communications and information technologies have long since entered the maritime transport system. Today, nautical information is provided by electronic systems, rather than a sextant and hand lead-line. But how reliable and resilient are they? Within its e-navigation strategy, the International Maritime Organisation (IMO) has identified the digitalisation of shipping to be a major challenge. This includes the implementation of system and data integrity into the maritime traffic system as well as increasing the resilience of navigation-relevant systems. Here, DLR scientists will bring their expertise in communications and navigation to the table.

DLR know-how for standardised navigation data

By Evelin Engler

Positioning. Navigation. Timing. In short – PNT. For several years now, an interdisciplinary expert team has dealt with the question of how ship-side provision of PNT data should be performed to meet the numerous accuracy and integrity requirements. Ship types and user needs are extremely diverse. The German Aerospace Center (DLR), together with the Federal Maritime and Hydrographic Agency (BSH), the Federal Waterways and Shipping Administration (WSV), and ship suppliers in coordination with the German Federal Ministry of Transport and Digital Infrastructure (BMVI), has developed a concept that is based on modularisation of the maritime PNT system architecture. It introduces a scaling of the system performance to specify minimum as well as demand-driven higher performance requirements. In June 2017, the Maritime Safety Committee (MSC) adopted the guidelines for ship-side positioning, navigation and time data processing.

The Guidelines establish a framework that classifies, structures and harmonises the ship-side provision of PNT data and associated integrity and status information using radionavigation receivers, PNT-relevant sensors and data sources as well as position reference systems. But why is it becoming increasingly important to standardise the software (guidelines) as well as the devices (performance standard)? In addition to economic aspects, the focus of IMO's standardisation activities is on the safety of shipping and the protection of maritime habitats. PNT data is essential for safe shipping because they are key to navigating a ship from one location to another, to avoid collisions and groundings, and to execute specific nautical tasks in an assisted, semi- or fully-automated way. Each application has its specific requirements on PNT data provision. For a small dinghy, for example, it is sufficient to know the current position. But the turning and docking of a large container ship requires accurately and reliably determining the location of the ship's hull in relation to the port basin. Position accuracies of a few tens of metres may be sufficient for ships in the middle of the ocean.

In April 1912 the Titanic collided with an iceberg south-east of Newfoundland and sank soon after in the North Atlantic. More than 1500 people lost their life. As a result, the first version of the 'International Convention for the Safety of Life at Sea (SOLAS)' came into being and specified minimum safety standards regarding the number of lifeboats, emergency equipment, along with safety procedures, including continuous radio watches. Since 1958 the International Maritime Organization (IMO), as a United Nations specialised agency, has been responsible for establishing the highest standards worldwide for safe, efficient and sustainable shipping.

Image: Raytheon-Anschütz

Modern shipping depends on reliable provision of PNT data. This is ensured by establishing quality standards for the data.

In straits, areas with high traffic densities and ports it is important to determine the location of each ship's hull with an accuracy of few metres in order to safely avoid collisions. The overall requirements for shipside PNT data provision have to be structured in a temporal, spatial and functional context, before suitable technological solutions may be identified, classified and ultimately standardised on the system or component level.

The special feature of the established guidelines is that they, for the first time, set out norms to manufacturers, yards, ship owners and ship suppliers, on how redundancy in the ship-side database might be used to achieve an evaluation of the integrity of PNT data in accordance with common global standards. This provides clarity regarding the quality and trustworthiness of currently available PNT data. Navigational staff on board of cruise liners, container ships and ferries as well as pilots in the ports of the world will be assisted as such to avoid misinterpretation of situation pictures and to make correct decisions in critical situations.

Research and standardisation are complementary development processes; together they shape the transition from today to tomorrow. Research has the task of addressing how systems can become more reliable or how to reduce the risks of accidents. The international standardisation bodies are responsible for deciding which of the solution alternatives deserves the 'best practice' predicate and ultimately will be standardised.

Evelin Engler is a researcher at the DLR Institute of Communications and Navigation and works with maritime standardisation bodies.

STRUCTURING OF PNT DATA OUTPUT

Which PNT data is needed – whether position and time or even the three-dimensional position of the ship – is now specified by the degree of PNT data provision.

Grade I

- Latitude and longitude
- Speed and course over ground (SOG and COG)
- Time

Grade II

- + Heading and rate of turn
- + Speed and course through water (STW and CTW)

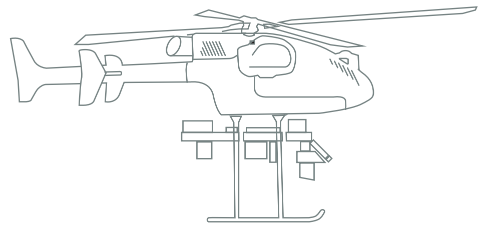
Grade III

- + Altitude
- + Depth

Grade IV

- + Heave, sway and surge
- + Yaw, pitch and roll

FLY ME TO THE MOON …



superARTIS helicopter becomes a lander – testing an autonomous lunar landing on Earth

By Anna Boos and Manuela Braun

Eighty circles – each half black, half white – extend across a five-hectare test site close to Braunschweig. For a day, this scenario represents the Moon and its cratered landscape, and an unmanned DLR research helicopter, superARTIS (Autonomous Rotorcraft Test bed for Intelligent Systems) becomes a lander, set to hover autonomously over the simulated lunar surface before touching down on the landing site. During the Moon landing back in 1969, things were quite different – as the Apollo 11 landing module made its way towards the lunar surface, astronauts Neil Armstrong and Buzz Aldrin noted that they were not descending toward their intended landing site, but were heading towards a crater strewn with boulders. Landing there was out of the question – it was too risky. Armstrong intervened, manually steering the 'Eagle' over the boulder-strewn lunar surface to find a smooth landing site. Without humans, the landing would not have been possible. The autopilot systems of the day were not capable of automatically detecting dangerous sites and avoiding them.

Today, a 'navigation system for the Moon' has become a necessity, partly due to the increased scientific requirements for unmanned missions. In the ATON (Autonomous Terrain-based Optical Navigation) project, DLR researchers are investigating how landing spacecraft can navigate to an optimal landing site as autonomously and accurately as possible. Four DLR institutes and one software facility are involved in the project. The researchers' goal is to develop software that automatically processes image and sensor data acquired during the approach for a landing on the Moon or any other celestial body, orientates itself with respect to the topography and determines the attitude, velocity and position of the spacecraft in real time. During this process, data from two navigation cameras, acceleration sensors and rate gyros, and a laser scanner is combined.

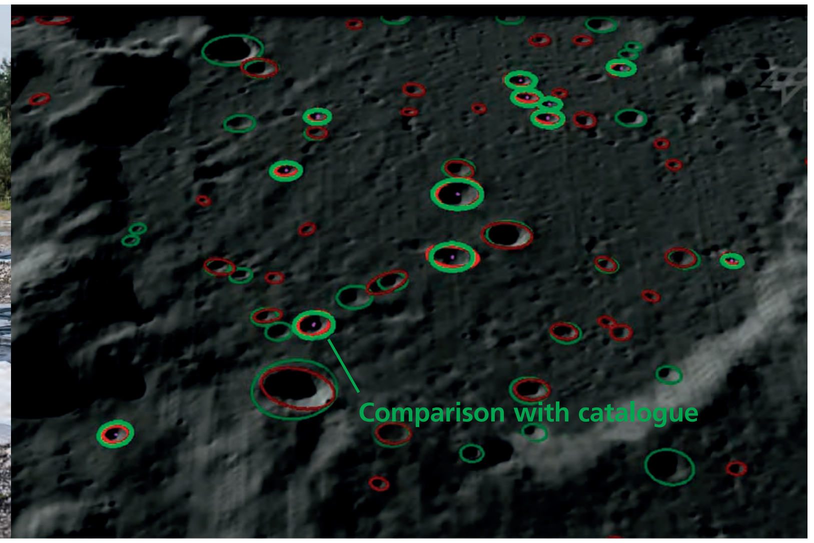
"Then it will be a matter of 'we want to land at this crater or that rille'," explains project leader Stephan Theil from the DLR Institute of Space Systems. "For instance, landing at the Moon's south pole would be interesting for research, as would be landing on comparatively narrow crater rims or near a future Moon base. But navigating a lander safely and precisely is still a major challenge. If the required level of accuracy is not achieved, we run the risk of the lander alighting in permanent shade on the crater floor, and thus losing it." Only precise landing manoeuvres and real-time evaluation of the landing site using a navigation system would minimise this risk. "ATON has brought us one step closer towards achieving this goal," Theil says.

Image: DLR/Moritz Küster

Hans Krüger from the Institute of Space Systems configures the on-board sensor array for the first flight test

Image: DLR/Moritz Küster

Tarpaulins represent the craters. They need to be spotless to help the camera correctly detect the contrast.



Craters and uneven surfaces cover the Moon in the simulated camera view of a lander as it approaches the surface. For the computer model, scientists used data from sources such as the US Lunar Reconnaissance Orbiter mission and the Japanese Kaguya (SELENE) mission. To make the simulation of the Moon as realistic as possible, solar radiation and the Moon's movement in space, for example, also had to be taken into account. In addition to the data 'seen' by the camera, the simulation also generates realistically computed data from other sensors on board the lander, such as acceleration measurements and the output from the laser scanner for remote measurements.

Image: DLR/Moritz Küster

Nikolaus Ammann (right) and Daniel Lüdtke monitor the flight test from the ground station

Image: DLR/Marek Kruszewski

Safety pilot Michael Kislat-Schmidt clears superARTIS for take-off

Scrubbing up for the flight test

On the flight test site, the first task is to scrub the 'craters' clean. Rain and wind from the previous weeks have covered the tarpaulins set up by the DLR researchers to recreate a cratered lunar landscape in dust and dirt. The 'craters' vary in diameter – from five metres for the biggest crater to just 20 centimetres for the smallest. "Our navigation camera orientates itself by measuring the contrast between the light and dark surfaces. If these are not clearly identifiable by the software as real craters, it will ultimately impair the navigation quality," explains Bolko Maass from the DLR Institute of Space Systems.

The researchers have been working on this project for seven years. They completed the first major step towards achieving their goal five years ago, when they created a realistic simulation model using available Moon data. "With the ATON simulation, we have developed a complete 3D model of the Moon, together with simulation software that creates images that a camera on board a landing module would see," explains Theil.

"Like a pilot looking out of the window for orientation, the software is designed to use camera images during the landing approach to independently determine where the lander is and which direction it is moving in." Craters and other prominent terrain formations on the Moon act as landmarks that the system uses in combination with other sensor information to determine its position. If no such landmarks can be detected, the software navigates using the movements visible in the images and accelerations and rotational rates measured by inertial sensors. Using this system, the required positional accuracy of approximately 100 metres can be well achieved at the end of the landing process.

Fit for the Moon and asteroids

The navigation software has already passed the first accuracy tests in simulations and the laboratory. Following the successful simulation of the landing approach, the software was tested in the Testbed for Robotic Optical Navigation (TRON) at the Institute of Space Systems in Bremen, where its movement relative to a model of the Moon was simulated using a robotic arm fitted with a camera. The model of the Moon depicts craters and other structures in three dimensions, and the light and shadows can be realistically recreated using an additional robotic arm equipped with a lamp that acts as an 'artificial Sun'. Development was continued with the purpose of making the technologies available for a future mission to the Moon or an asteroid. To do so, the researchers further developed and optimised algorithms and software, and implemented them for operation on real-time computers.

But in order to someday be used in the proximity of distant celestial bodies, ATON must first successfully complete this test flight. Concentrated silence fills the simulated lunar landscape. Everyone is prepared and knows what to do now – they have gone over the necessary steps many times. The mobile ground station is moved into position; antennas for radio traffic are set up; the 1.3-metre rotor blades are attached to the helicopter and the sensors are checked once again. "Our tasks during the flight tests with superARTIS are clearly allocated," explains flight-test leader Stefan Krause from the DLR Institute of Flight Systems, who is responsible for the proper and safe execution of today's flights. The team includes a safety pilot, who will take over control of the unmanned helicopter if necessary, and three scientists who monitor the flight control systems and the ATON software in the ground station.

Safety pilot Michael Kislat-Schmidt sports an orange safety vest. He is the only person allowed to stand within a few metres of superARTIS on the airfield. The other colleagues are in the mobile ground station or in the safety area behind it. With a thumbs-up, Kislat-Schmidt signals the start of the test. With the remote control in hand, he commands the helicopter to take off. As the rotor blades start to spin around, they stir up a small cloud of dust. The skids on the 85-kilogram helicopter gently rise from the ground and superARTIS lifts off. Andreas Voigt takes over control from the ground station and commands the helicopter to fly to the starting point of its Moon mission.

Cameras, sensors and scanners

Hovering 50 metres above the ground, the unmanned helicopter's sensors are directed at the ground covered by the 'crater' landscape below. superARTIS is equipped with a full 25 kilograms of payload for the simulated lunar landing. In the ground station, Daniel Lüdtke from the DLR Simulation and Software Technology Facility monitors the screens and checks whether the values from the sensors in the ATON software are fusing correctly. "OK, the ATON software is running," he says, giving the start signal for the test flight. Nikolaus Ammann from the DLR Institute of Flight Systems switches from the helicopter's built-in sensor fusion to the ATON system. superARTIS is now navigating via the Moon landing software and is independently following the predefined landing trajectory.

The helicopter gently descends towards the ground at a speed of one metre per second. Lüdtke's gaze is still intently directed at the screens. "Based on the craters detected by the camera and the movements seen in the images, we can determine the aircraft's position," Lüdtke explains. "The ATON sensor fusion combines this positional data with other sensor data and hence determines the overall flight state, including the aircraft's attitude, velocity and position," Ammann adds. "This flight state, calculated from optical navigation data, is independent of GPS and can be determined in the same way on the Moon."

The craters guide superARTIS along a safe path to its landing site. The helicopter has fulfilled its mission as a lander. The DLR researchers must now assess the data acquired during the flight test. They can load the sensor data from the flight test into the simulation and run through a virtual flight test again. In this way, the software can be further optimised. The flight tests mark the successful completion of this important phase of the ATON project. The scientists will use the findings to further develop the ATON navigation system. The long-term goal of this DLR research project is to develop and build a navigation system for future space missions that send landing probes to explore planets, moons and asteroids.

Anna Boos is responsible for public relations, among other areas, at the DLR Institute of Flight Systems. **Manuela Braun** is space editor/writer at DLR.

PARTICIPATING INSTITUTES

Institute of Space Systems –
Department of Navigation and Control Systems

Institute of Flight Systems –
Department of Unmanned Aircraft

Institute of Optical Sensor Systems –
Department of Information Processing of Optical Systems

Institute of Robotics and Mechatronics –
Department of Perception and Cognition

DLR Simulation and Software Technology Facility –
Department of Software for Space Systems and Interactive Visualization

Cassini's swan song

15 September 2017 will be a date to remember in space history. Almost exactly 60 years after the Space Age began with Sputnik 1, one of the largest – but also most magnificent and scientifically productive – missions aimed at exploring the Solar System is coming to an end. For the 22nd and final time, the Cassini space probe will fly through the plane of Saturn's rings and plunge into the planet's atmosphere at a speed of more than 75,000 kilometres per hour. At around midday our time, the orbiter – which was launched back in 1997 and has orbited the second largest planet in the Solar System almost 300 times since 2004 – will burn up in mere seconds.

This might be the end for Cassini – but it leaves behind an astounding legacy! For 13 years, the camera system has acquired 370,000 images, and countless recordings have been gathered from the 11 experiments. On 14 January 2005, Cassini released the European lander Huygens, which successfully landed on Titan, Saturn's largest moon. Cassini-Huygens will have a place in the spacecraft Hall of Fame – side by side with Viking, Voyager and Galileo.

DLR.de/en/Saturn

Ulrich Köhler

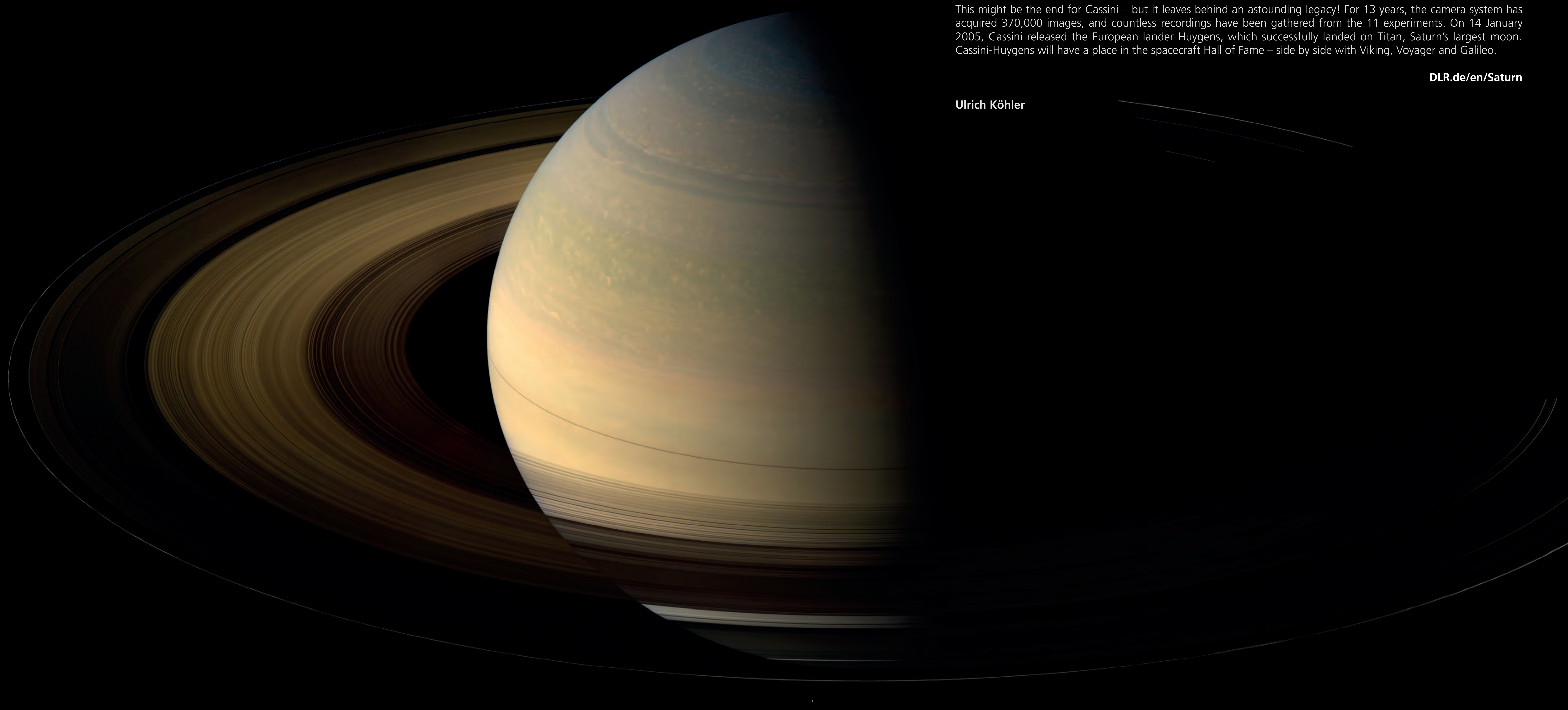
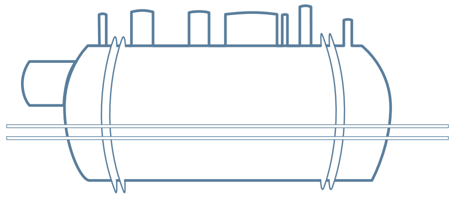


Image: NASA/JPL/Space Science Institute

THE POWER OF SALT

Converting the output of variable energy sources such as solar plants and wind farms into a reliable power source is one of the major challenges faced by energy research. High-temperature thermal storage systems are a key technology for addressing this problem because they represent a cost-effective solution for storing large quantities of energy, which can then be used to generate electric power or serve as a direct heat source. On 15 September 2017, DLR researchers commissioned a globally unique plant, in which the industrial components needed for molten salt storage can be tested under realistic operating conditions. Project Manager Thomas Bauer introduces the plant and explains why molten salt allows massive energy storage. The interview was conducted by Michel Winand, who works in the Department of Public Affairs and Communications at the DLR site in Cologne.



TESIS – Thermal storage using molten salt for the Energiewende

Dr Bauer, you have just commissioned a new testing facility – TESIS. What makes it special?
: The Test Facility for Thermal Energy Storage in Molten Salts – which we call TESIS for short – is divided into two sub-systems. TESIS:store will be used for storage development, and TESIS:com to test components. With the new facility, we are stepping away from laboratory-scale work and conducting research and development on an almost industrial scale. TESIS:store is the largest research facility in the world designed to investigate new single tank molten salt storage concepts.

What does that mean?
: Storing excess heat in one large tank reduces the cost of the storage facility, yielding potential savings of up to 40 percent compared to state-of-the-art two tank systems. But a lot of questions must still be answered regarding materials, heat transfer, thermomechanics and system integration.

What characterises the second sub-facility?
: TESIS:com is also unique. We can use it to investigate components to be used in molten salt storage, and for further developing process and measurement technologies. The tests are carried out in a climate-controlled building under defined conditions. We can set up and adjust the research equipment flexibly,

The globally unique test facility for Thermal Energy Storage In molten Salts (TESIS) enables industry to investigate components for molten salt thermal storage systems under realistic operating conditions

The TESIS system is designed in such a way that the flow of molten masses and their temperatures can be regulated differently depending on the test requirements

according to the customer's requirements. It is also possible to test the functional integrity under extreme operating conditions, as the setup is located in a protected area with safety equipment.

What are the advantages of molten salt over other storage media?

: These lie in the medium itself. Molten salts can be used at temperatures of between 170 and 560 degrees Celsius depending on the mixtures. The salts are neither toxic nor flammable. Furthermore, molten salt is easy to pump, but is not pressurised at high temperatures, as is the case with water, for example. All that makes salt interesting not only as a storage medium but also as a heat carrier over larger distances. In addition, the salt storage concept has another advantage – separate components for storage capacity and output power lead to a high flexibility and controllability in operation. The storage capacity is housed in large containers that are relatively inexpensive. Power components, such as heat exchangers, adapted to the particular requirements of the overall system can be used for energy charging and discharging. For example, the storage medium can be charged from various sources – exhaust gas, thermal oil, electric heat or solar heat.

Which branches of industry might find salt storage systems of interest?

: At the moment, mainly solar power plants situated in Earth's Sun belt. Here, it is a matter of reducing specific storage costs to make the facilities profitable. However, in the future we see areas of application for this storage technology in other latitudes, including Germany. Energy-intensive industrial processes are candidates for this. Wherever steel, iron and non-ferrous metals, glass, cement or chemical products are being produced, large quantities of heat are generated and then not used optimally. Molten salt thermal storage systems could increase the energy efficiency of such companies. Variable power from wind farms or photovoltaic facilities could also be converted into high-temperature heat. This heat can be stored and supplied without fluctuation of the production processes and power cycles.

Even conventional fossil fuel power plants would benefit from this storage technology. The transition process that they are undergoing could be handled more flexibly with integrated thermal storage systems. This is important for further expansion of wind and photovoltaic installations in the future.

TESIS:com

Objective

- Testing and qualification of components for molten salt storage technology, for research and industry – for example, valves, solar receiver tubes, measurement techniques
- Process technology investigations such as cooling processes

Operating parameters
From 150 to 560 degrees Celsius

Maximum mass flow rate
8 kilograms per second

Maximum heating or cooling power
420 Kilowatt

TESIS:store

Objective

- Demonstration of a single-tank storage system with filler material for thermal storage
- Investigation of heat and mass transfer, thermomechanics, material compatibility, process engineering, scaling and system integration

Operating parameters
From 150 to 560 degrees Celsius

Storage capacity
200 kilowatt-hours per cubic metre with 20 cubic metres and four kilograms per second

One of the most important issues in energy research is dealing with variable energy from the Sun and wind..

: Yes, exactly. Converting variable power from renewable energy sources into controllable electricity is a key issue. Energy storage is the solution here. But batteries are too expensive for storage tasks in the gigawatt-hour range. Hence, we are investigating new power storage technologies using efficient thermal energy storage. The basic components for molten salt systems – electric heaters, storage units and steam-driven power plant components, for example – are available, but their efficiency levels are still too low for some applications.

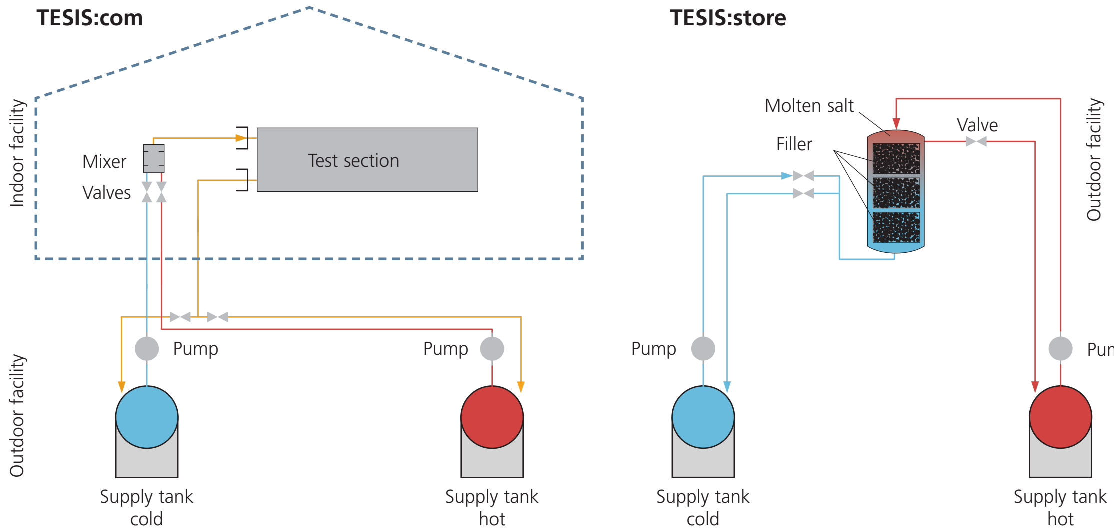
The new TESIS facility will allow you to drive research forward. When do you expect efficient molten salt storage technology to be available to industry?

: Molten salt storage technology has already been widely employed in solar thermal power plants; it has been used commercially in this field for approximately 10 years with a total global capacity of more than 30,000 MWh_{th}. Technology transfer with demonstration projects in new areas of application, such as the industrial process heat sector or power plant technology, is entirely possible in the next few years. Questions regarding system integration need to be answered, and industry's specific needs must be identified. It might be beneficial here that DLR is developing new, cost-effective molten salt storage concepts in addition to the two-tank systems already available. For example, the single tank storage concept mentioned at the start. Following its demonstration in the TESIS:store facility in a scale of four MWh, the technology requires further upscaling and pilot installations in the target applications. First commercial implementations will be feasible in around 10 years time.

What impresses you the most about this project?

: With TESIS, we will gain hands-on experience of process technologies and operational aspects for molten salt storage technology. It is as exciting as it is challenging. We will be able to direct our research towards the new issues that arise. This is an opportunity that brings with it a lot of work, but a lot of satisfaction as well. We are also working on the Energiewende (Energy Transition), in an exciting and dynamic environment, with possibilities for introducing new technological developments. We are doing our bit to help shape the future.

Thomas Bauer …
… obtained a degree in Electronics and Information Technology in Heilbronn before completing a doctorate degree in thermophotovoltaics and thermal engineering in England. His scientific career at DLR began in 2005 in Stuttgart in the Department of Thermal Process Technology at the Institute of Engineering Thermodynamics. In 2012, he moved to Cologne, where, since 2015, he has been responsible for research ranging from materials to systems in the Department of Thermal Systems for Fluids.



Simplified schematic diagram of the two TESIS systems

TESIS staff members set the process gas system

DREAMS IN THE COCKPIT AND WONDER IN THE WAREHOUSE

Sleep in a jumbo jet and discover aviation history at Stockholm's Arlanda Airport

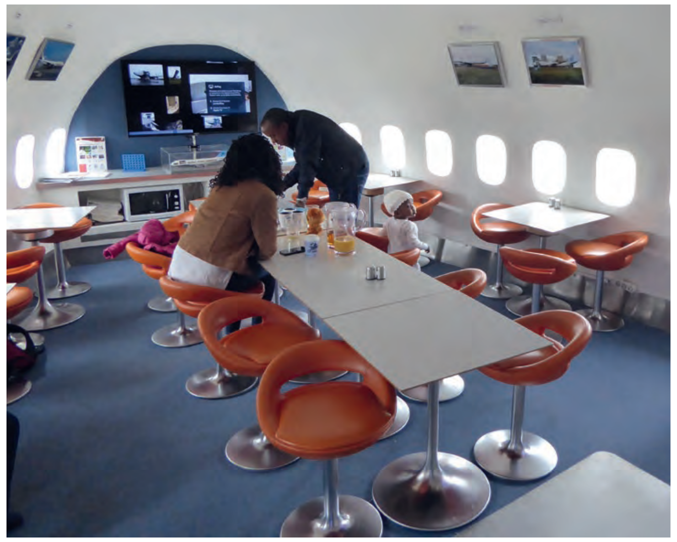
By Hans-Leo Richter

Airport hotels rarely crop up in notable hotel rankings – why would they? They are designed for the single purpose of providing the most convenient accommodation possible for travellers in transit, and perhaps a suitable setting for guests attending conferences. That does not leave much room for creativity, which makes the rare exceptions all the more refreshing. One example of such a place can be found at Arlanda, Stockholm's international airport, just 40 kilometres north of the sublime Swedish capital. Here, an unequivocally unconventional hostel offers accommodation to travellers in transit. It could not be more original and more historic at the same time.

Newcomers are in for a treat: an actual decommissioned Boeing 747 jumbo jet repurposed to accommodate them. The former long-haul aircraft is a hostel with a truly unique ambience – Jumbostay. The jumbo, originally built for Singapore Airlines before serving the legendary PanAm, ended its career with Transjet, a comparatively small Swedish airline that went out of business a long time ago. Today, the aircraft holds 33 sleeping areas, the absolute show-stopper being the – not exactly inexpensive – double suite in the cockpit. Rather than a standard radio alarm clock, hotel guests wake up to the yoke, an artificial horizon, an altimeter, a variometer, a gyrocompass and other circular displays. Almost all the operation controls and displays are still in their original condition, but in place of the former head panel there is now a flat screen TV – something no guest should have to do without.

A hotel normally looks a bit different: At Arlanda Airport in Stockholm, you can sleep in the Boeing 747 hostel or cockpit suite.

How does a cocktail on an aircraft wing sound? Guests are expressly invited to go for a 'wing walk' – that is, weather permitting.



Instead of just first class passengers, all guests have access to a nice bar for breakfast and an evening drink.

More accommodation options are located in the four engine nacelles, in the former landing gear bay and in the tail section of the Boeing – what was formerly a compartment reserved for the flight data recorder (the black box). All the sleeping areas have windows, as well as air conditioning and sanitary facilities. The former cabin space boasts small single or double rooms on either side of the aisle, which has been converted into a hotel-style corridor. On the upper deck – where first and business class passengers used to enjoy a drink at the bar – is a small conference room with leather armchairs and all sorts of conference equipment.

Finally, in the nose area of the aircraft, formerly reserved for first class passengers, is a small bar. Breakfast is served here, even though the plastic stools do not look very inviting. In the evening, guests can enjoy a drink out on the left wing, weather permitting. In fact, everyone is expressly encouraged to do a little wing walking.

Just a few hundred metres walk from the Jumbohostel is an inconspicuous-looking former storage building that packs a punch. Labelled the 'Arlanda Flygsamlingar', it houses a truly remarkable collection of old aircraft, engines, single components and much more.

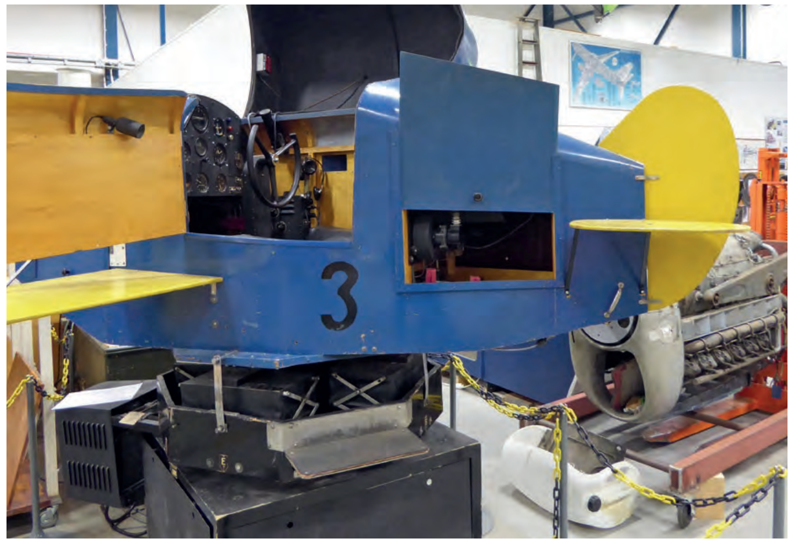
The name 'Arlanda Air Collections' is very appropriate, as this is not an official aviation museum, but a private collection that has existed since autumn 2001 and survives on the voluntary efforts of its patrons and friends alone. Its most historically significant aircraft is, without doubt, a Junkers W 34 that 'hovers' very strikingly beneath the warehouse roof. This model is a slightly more powerful version of the famous W 33, which was the first to cross the Atlantic in an east-west direction on 12 April 1928, flown by Hermann Köhl, James Fitzmaurice and Baron von Hünefeld.

The W 33/34 is a single-engine low-wing aircraft with a typical light corrugated-iron metal design, as was so characteristic of the early Junkers models. Last summer the W 34 was unfortunately hanging wingless from the roof while the wings underwent further restoration work in the immediately adjacent workshop. The model exhibited here was built under licence in 1935 in Limhamn, Sweden. It is equipped with a Bristol Mercury radial engine, plus the NACA hood: a special, aerodynamically advantageous cover for radial engines that was highly modern in its day. On the side, you can still see the logo of the 'Lapplandsflyg', a Swedish domestic flight operator for which the cantilever-wing aircraft was last used from 1956 to 1961.

However, the Junkers W 34 is not the only aircraft to originally come from Germany. Also worth seeing are the Bücker Jungmann biplane, the KL35 Klemm cantilever-wing aircraft, a Rieseler RIII light aircraft from 1923, and a 1917 Albatros BII. No less interesting are the numerous early commercial aircraft from the piston-engine era, such as a 1942 Lockheed Electra (for up to eight passengers) and a Lockheed Lodestar from the same period (for up to 14 passengers). The elegant, twin-engine cantilever-wing Lockheed Electra, in particular, achieved a certain amount of fame, primarily in the United States in the pre-war years, as it was an aircraft commonly used by the US-American aviatrix Amelia Earhart. It was with this model that she embarked on her last record-setting flight in 1937, which ultimately came to an end over the Pacific when the aircraft disappeared without a trace under circumstances that are still a mystery today.

Great aviation tradition: In the centre of the image is the Junkers W 34, almost fully restored with great care, even if it is still missing its wings.

Emanuel Swedenborg, the Swedish visionary, designed this 'machine for flying in the air' in 1716. Unfortunately he never got to test it.



The classic Link Trainer – the 'mother' of all flight simulators since the early 1930s.

The Royal Institute of Technology's (KTH) wind tunnel carried out analyses at a wind speed of up to 40 metres per second from the 1930s onwards

Among the range of small piston-engine commercial aircraft is the Dove, another short-haul aircraft for up to nine passengers that was an early development from de Havilland. Several very attractive gliders from the plywood era hang from the roof of the long warehouse – a DFS Weihe A3 and the renowned 'Grunau Baby'. Another well-known model hangs from the warehouse roof to greet visitors: a minimalistic ultralight model with an interesting frame. Called the 'Flying Flea', it is also exhibited in the Danish aviation museum (see DLR Magazine 150 from June 2016).

Cockpits also catch the eye, such as that of the French medium-haul commercial aircraft the Sud Aviation Caravelle, or a simulator cockpit for a twin-engine Convair 440 Metropolitan commercial aircraft – both typical 'clockwork' cockpits from the period long before today's glass cockpit displays. A recognisably crumpled cockpit is a reminder of an aircraft accident in December 1991, when a fully laden McDonnell Douglas MD-81 lost both engines shortly after take-off in Arlanda due to insufficient de-icing. The crew masterfully made an emergency landing in a field, during which the fuselage broke up into three parts. Even so, all the occupants survived, and just a few injuries were sustained. Now this cockpit section has found a home in the Flygsamlingar after many idle years in a scrapyard. However, in place of the actual instruments are photographs of them.

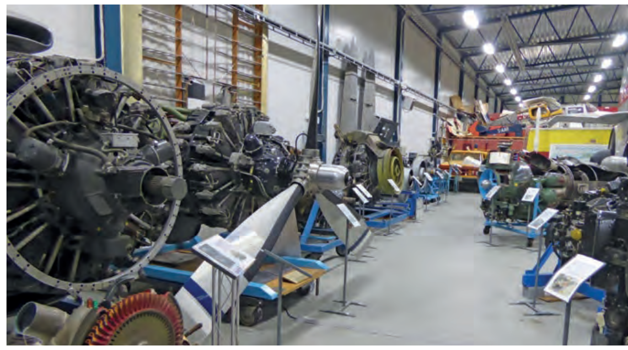
Numerous individual components, such as various propellers of all sizes, as well as many piston and jet engines, complete the collection. Also worth seeing are the range of dioramas representing historical aviation scenes, such as the take-off preparations for a Farman-Voisin biplane in 1907. Last but not least, the Flygsamlingar has a small model wind tunnel and a number of flight simulators, including the renowned Link Trainer, regarded as the 'mother' of all subsequent simulator cockpits.

Even though the educational museum concept is somewhat missing, this private collection still offers interesting insights into the multifaceted history of aviation – and not just in Sweden. And if a certain level of fatigue sets in after viewing the many aviation veterans, there may still be room for dreaming in the cockpit of the jumbo jet …

www.jumbostay.com
www.arlandaflygsamlingar.se

A Lockheed L 18-56 Lodestar from 1943 is being prepared for repainting. The dummy of a mechanic on the wing strikingly represents the working method.

The cockpit of a small Lockheed Electra 12-26 commercial aircraft from 1942. Interesting features include the white-marked instrument area for the artificial horizon, the altimeter, the speed display, the compass and the turn-and-bank indicator.



Numerous piston and jet engines demonstrate a representative cross section of historical aircraft engines

HIDDEN FIGURES

The film **Hidden Figures** takes us back to the United States of America in the early 1960s – a nation divided by segregation issues and heavily involved in the mid-twentieth century space race. Against this backdrop, three brilliant African-American women are featured that play a pivotal role in NASA's space programme. The film highlights their struggle for recognition in a time characterised by superstition and fear.

The main character, Katherine Johnson, played by the ever-charming Taraji P. Henson – an electrical engineer turned actress – works as one of the 'coloured computers', African-American female co-workers that carry out the calculations necessary for the space programme at the strictly segregated NASA offices in Hampton, Virginia. When Katherine gets bumped up from the 'coloured people only' West Wing building to join Al Harrison's team tasked with sending the first US-American into Earth orbit after a successful Russian satellite launch, the pressure is on Katherine to prove her worth as an analytical geometry engineer.

As the only non-white person – and female at that – Katherine has to face some of the worst segregational and sexual bias. From separate coffee pots to having to cross the whole campus to go to the 'right' toilet – issues that seem ridiculous now and might make you laugh but have a very sad background of truth in them. Tension builds up as the Russians seem to effortlessly launch satellite after satellite and beat the US in putting mankind in orbit.

Meanwhile, Dorothy Vaughan (Octavia Spencer), unofficial supervisor of the 'coloured computer ladies' sees an opportunity arise when technology shifts the focus from human computers to electronic ones. Teaching herself FORTRAN from a library book she unlawfully had to smuggle out of the 'whites' section, she is able to start the newly installed machines and work her way up to supervise the Programming Department. Best friend Mary Jackson (Janelle Monáe Robinson), aspiring engineer herself, tries to become the first female engineer at NASA. She has her day in court where she gains the right to follow night classes at an 'all-white' school.

Weaved into all of this are some highlights from the turning point in the two-nation space race – some heroics from Kevin Costner in his role of Al Harrison as he single-handedly tears down all toilet signs muttering the epic words: "Here at NASA will all pee the same color."

The film reaches its pinnacle as John Glenn enters his Friendship 7 capsule to be launched into orbit on an Atlas rocket and CapCom learns that the newly inaugurated IBM machines have slipped up and the calculations on the capsule's trajectory seem to be off. John asks for Katherine personally to check the math before setting off on his epic journey around Earth. Will Katherine be able to live up to his expectations?

If not for the story, the background, or a love of science, the film is worth seeing if only for the superb music.

Linda Carrette

WOMEN IN SCIENCE – 50 FEARLESS PIONEERS WHO CHANGED THE WORLD

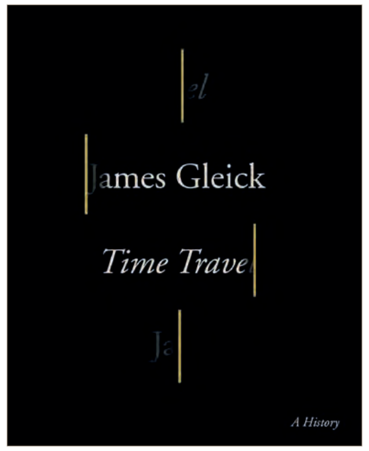
Throughout history, both men and women have wondered about shooting stars, eclipses, creatures living on the bottom of the ocean, what made people sick, how they could be cured and more. However, women have had limited opportunities to satiate their curiosity through research and exploration, and even today are significantly underrepresented in Science, Technology, Engineering and Mathematics (STEM). In her captivatingly illustrated **Women in Science**, Rachel Ignotofsky presents the scientific contributions of 50 notable female scientists, hoping to inspire young women to follow in their footsteps.

Among the profiles are well-known figures such as physicist and chemist Marie Curie, the only woman to win the Nobel Prize in two different disciplines, and primatologist Jane Goodall, whose groundbreaking research among chimpanzees revealed that they are socially and biologically very close to humans. Lesser-known pioneers featured in the book include astronomer and mathematician Wang Zhenyi, who explained eclipses; botanist Mary Agnes Chase, collector of over 10,000 different grass specimens from around the world; Mamie Phipps Clark, whose research into the psychological effects of segregation contributed to the abolishment of segregation in public schools in the United States; entomologist Maria Sibylla Merian, who demystified the relationship between caterpillars and butterflies; volcanologist Katia Krafft, explorer of volcanoes; and physicist and mathematician Katherine Johnson, who successfully calculated the trajectory for the first manned mission to the Moon in 1969.

Although initially aimed at girls and young women, the book provides an entertaining read for an older audience as well. Let's hope that this celebration of scientific success will inspire young women to pursue careers as engineers, mathematicians, physicists, chemists, neurologists, geologists, botanists, astronomers, paleontologists, psychologists, writers, doctors, inventors and astronauts.

Merel Groentjes

WHAT IS TIME?



What hasn't been said about time travel, a concept that has so saturated modern day popular culture? That said, it's hard to believe that the marriage of time and travel was only achieved, according to James Gleick, just over 100 years ago by H.G. Wells. Responding to winds of change that rattled the idea of time and space, Wells penned The Time Traveller. But travelling back in time (if you will) to trace the development of this idea is a feat in itself. In **Time Travel: A History**, Gleick does a fine job of stringing together the scientific, philosophical, technological, and literary trends that led to it in a tone that is lightheartedly serious throughout the book.

Gleick, however, explores very little that is new on the topic in what often feel like repetitive passages. But perhaps that's the truest reflection of the impact of time travel on our contemporary lives: we've heard of it, we've watched it, we've read it, we've debated it, we've even wished for it. Nearly every modern life has come into contact with the idea of time travel, but often cannot always put a finger on how or why or what or where. This book tries to place these questions, to contextualise the idea of time and timelessness – to the extent that this is possible. So, if at times this book feels like a lot and a little, it is doing the concept of time travel justice. Isn't that, after all, how we would expect to feel as time travelers? Both foreign and familiar? One thing is sure – you'll definitely pick up a few fun facts to share at your next dinner party.

Laylan Saadaldin

RECOMMENDED LINKS

HAVE YOU TUNED IN?
https://soundcloud.com/nasa
The hissing of a space launch system (SLS) in test operation, thunderstorms on Jupiter or even radio waves, which sound like birdsong in the jungle, can be found in NASA's soundcloud. Also interesting are the various podcasts with experts on the International Space Station, the search for life on Mars, or the discovery of exoplanets.

CONSTANT RESTLESSNESS
http://bit.ly/2u1PvPP
Etna is never quiet – during the ROBEX mission on the volcano, the DLR researchers experienced this first hand. The tried and tested technologies will enable an autonomous mission with seismic measurements on the Moon. The National Institute of Geophysics and Volcanology (INGV) shows a real-time demonstration of Mount Etna's daily activity.

SHIPS AHOY
http://bit.ly/2vb7lVo
Ship traffic and the quantity of ship information sent are increasing. Scientists at DLR are therefore working to increase safety and to provide a more reliable picture of the situation by developing and evaluating novel radio signals. The website shows shipping traffic worldwide, the size of the ships, where they are going and what they look like.

ALL ABOUT EARTH
https://go.nasa.gov/2qDXxxT
When the two Voyager probes were launched 40 years ago, they carried with them 'Golden Records' – information about Earth for extraterrestrial life forms. 115 pictures, audio samples with bird songs or wind noise, greetings in 55 languages and music from different cultures have been travelling through the Solar System since then. The content of the 'Golden Records' can be viewed on the NASA site.

CASSINI'S GRAND FINALE
http://bit.ly/2n8OBm7
Cassini's Grand Finale is in many ways like a brand new mission. NASA's Cassini spacecraft dove through the unexplored space between Saturn and its rings 22 times. What we learn from these ultra-close passes over the planet could be some of the most exciting revelations ever returned by the long-lived spacecraft. This animated video tells the story of Cassini's final, daring assignment and looks back at what the mission has accomplished.

About DLR

DLR, the German Aerospace Center, is Germany's national research centre for aeronautics and space. Its extensive research and development work in aeronautics, space, energy, transport, digitalisation and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (Headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Göttingen, Hamburg, Jena, Jülich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington DC.

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